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DISCOVERY

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The Progress of Science

Science and Strategic Air Power

The contribution of scientists and engineers to the success of the raid which No. 617 Squadron of the Royal Air Force carried out against the Mohne, Sorpe and Eder dams in May 1934 was touched on in the book *Enemy Coast Ahead*, which was written by the leader of the raid, the late Wing-Commander Guy Gibson. This aspect of that brilliant exploit, which demonstrated beyond a shadow of doubt that strategic air power had reached the stage when it had to be considered as a decisive factor in warfare, was developed in Leonard Cottrell's excellent feature programme entitled "The Dam Busters", which was based on Paul Brickhill's book of the same title.

War has been revolutionised by the development of air power, which proved that it could be absolutely decisive once atomic explosives were added to the armour of the aeroplane. Science working hand in glove with technology can take full credit for this revolution.

The technical details of the preparation for the raid on Ruhr dams can be obtained by a close reading of the two books just mentioned, together with a third book, *No. 5 Bomber Group R.A.F.*, by W. J. Lawrence, which has just been published by Faber and Faber.

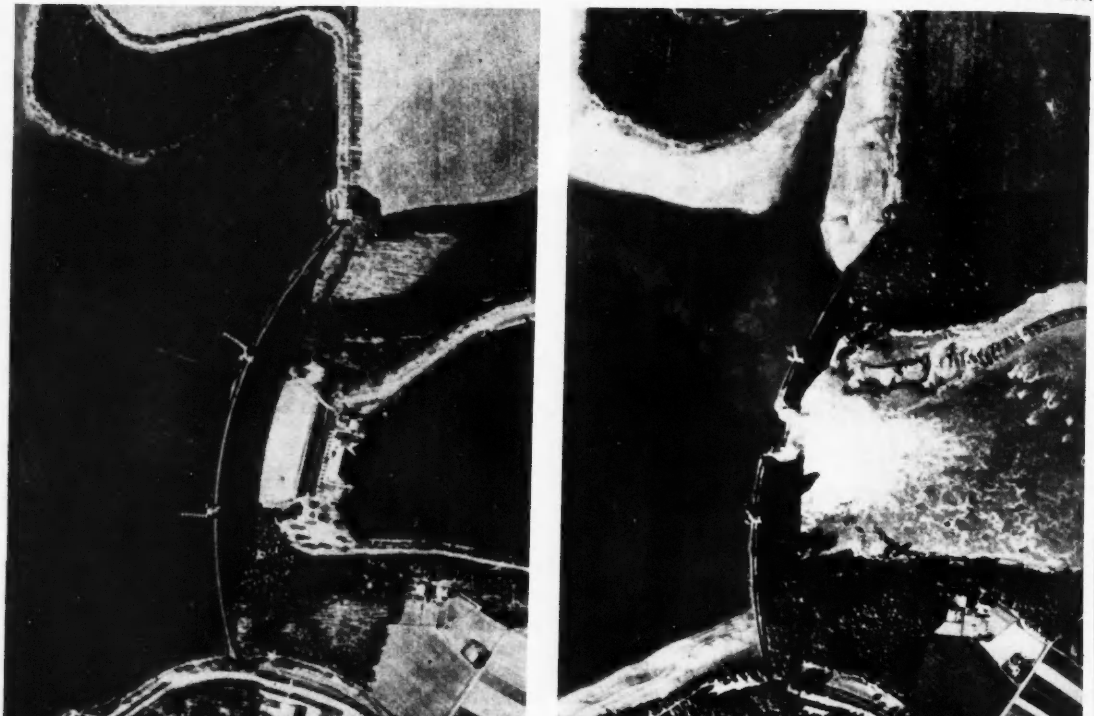
In his Foreword, Air Chief Marshal Cochrane, who planned this R.A.F. operation, stresses the preliminaries to such a raid; he refers to the bombing up of the aircraft, the obtaining of maps and reconnaissance photographs, the forecasting of weather conditions over the targets. Then there were matters of navigation, involving such aids as *Oboe*, *Gee* and *H2S* that the radar scientists had developed, though it would appear from this book that none of these radar devices proved perfect in the operations of Bomber Command, and indeed on occasions they represented nothing more than a dead and extra weight, which reduced air speed and thereby reduced the bomber's chance of survival.

Science clearly has an important bearing on all these preliminaries to a raid.

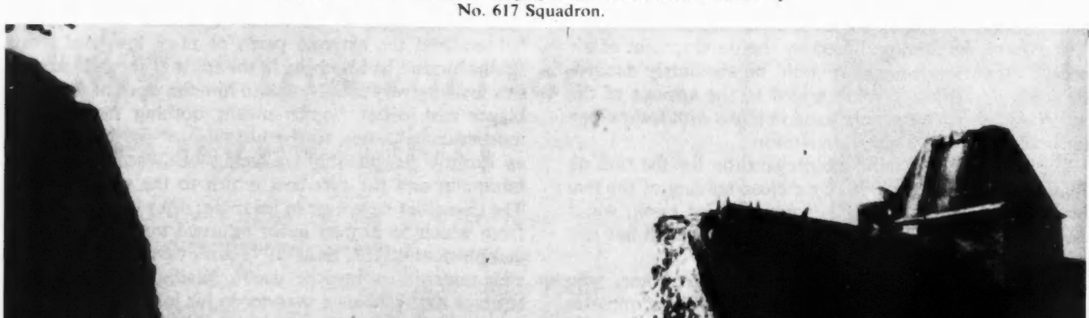
The idea of the raid was born in the fertile imagination of a scientist—that genius of armament research, B. N. Wallis, F.R.S. His conception was so startling in its novelty—he proposed to plant a comparatively small explosive charge right next to the wall of a dam so as to punch a hole in the wall, provided that the bomb aiming was accurate enough—that it was met by a wall of hostility and opposition compared with which the Mohne dam's hundred feet of concrete seemed quite thin. He had to fight against high Air Ministry officials and against technical experts; had it not been for the fact that he reached the ear of Churchill via 'Bomber' Harris the raid would never have materialised. The doggedness with which Wallis fought for his project (he even went so far as to tender his resignation when he was ordered to drop the scheme) was magnificent, and comparable to the spirit of the hundred and thirty-three airmen who pressed home their attack against the dams regardless of flak, night fighters and the extreme perils of ultra low-level flying. Wallis himself had nothing of the spirit of the militarist; he saw his duty very simply, and to him the work of perfecting bigger and better bombs meant nothing more than a modest contribution to the objective of finishing the war as quickly as possible, reducing our casualties to the minimum and the speediest return to the ways of peace. The casualties were ever in his mind; after the Mohne raid, from which 56 airmen never returned out of the original complement of 133, he said: "I can't think of the raid as a step towards ending the war." Wallis had the kind of courage that enables a man to do his job regardless of the cost to himself.

In March 1943 the raid was "on". The date for the raid was to be in May, and it was estimated that only three nights would be ideal for the raid. Two essential conditions were needed: the moon must be high, the water must reach within about four feet of the top of the dams, so that the water itself could exert the maximum pressure on the breach made in the dam by the mines. If the opportunity was missed in 1943 then the whole project would have to be put off until the same month twelve months later. So there were only three months in which to *develop* the various technical items required to give the raid a fair chance of success.

A special squadron, No. 617 Squadron, was formed at Scampton. The whole operation, "Operation Chastise", was a top secret, so the airmen in the squadron could be told very little about the scheme. All they knew was that



(*Left*) The Mohne Dam. (*Right*) Dam breached after attack by No. 617 Squadron.



The Mohne Dam. This photograph, found in German archives towards the end of the war, was taken four hours after the operation was over.

they had to practise night flying over water at a precise height and at a precise speed, and that the ultimate objective was the dropping of a mine on a target scarcely larger than a tennis court.

There were only six weeks left in which to achieve this almost impossible standard of low-level flying and accuracy of bomb aiming. Science stepped in to enable them to take advantage of all the hours there were before the raid; they were able to practice flying under *artificial* night conditions, the crews wearing yellow goggles and the windows of the aircraft being painted in the complementary colour, blue.

A simple range finder, so simple in fact that the airmen thought it was ridiculous and could not possibly work, was designed by Wing-Commander C. L. Dann of the Ministry of Aircraft Production. Then came the problem of flying steadily at an exact height over water just prior to the release of the mine. Sir Ben Lockspeiser of the M.A.P. (now head of the D.S.I.R.) solved this problem. Two Aldis lights were fitted in the nose and belly of a Lancaster, and the two slanting beams intersected at a fixed distance below the aircraft. The aircraft would be at exactly the right height when the two beams merged to produce a single spot of light on the water.

Meantime Wallis had been working on a modification of the mine. This was so designed that it would have to be released from a height of 60 feet from an aircraft flying at 232 miles an hour. Early in May an inert dummy mine was successfully released from that height at that speed, and "finally an active sample of the weapon was dropped and exploded according to plan."

One of the most difficult problems was to provide the attacking force with an effective intercommunication system. New radio frequencies that promised to be free from interference were tried out, but proved an absolute and complete failure. Then, at last, as late as May 6, it was decided that V.H.F. radio telephones should be fitted into twenty Lancasters of No. 617 Squadron. The job was completed satisfactorily by May 11.

Meantime there were dress rehearsals of the raid. A film studio set up framework structures on the water barrage in reservoirs in Uppingham and Colchester, and the crews practised bomb aiming on these dummy dams. The airmen were also required to release dummy mines on the range near Manston aerodrome. In one trial six out of twelve aircraft were seriously damaged, with rear turrets knocked in, elevators smashed, and fins bent. These Lancasters had been flying a little too low when they released their mines and although these were inert they made a great splash when they hit the water.

Meantime met. flights were made over the Atlantic, as well as eastwards across Norway, so that the weather forecasts could be made as accurate as possible.

The attack was launched on the night of May 16–17. Nineteen Lancasters took off. They crossed the sea using *Gee* as an aid to navigation, but once they reached land again navigation had to be done visually. They flew so low that the bomb aimers had perpetually to warn the pilots to gain height otherwise they would hit trees or high-tension electric cables.

The rest is now written into history. Two mines breached the Mohne Dam—the hole made was about 150 feet across, and the 134 million tons of water held back by the dam was released as a huge cataract. "It was moving in a huge wave, and in front of this Gibson could see the headlights of cars racing for safety. The headlights changed colour, first to green and then eventually to dark purple, as the water overtook them. The water swept on towards the eastern end of the Ruhr valley. The power house beside the dam was by now completely submerged." Back to Group Headquarters, where Wallis was waiting "like an expectant father", went the code word "Nigger"—the first dam had gone.

Then came the turn of the Eder Dam, more difficult to attack because of the topography and the fact that all the valleys were full of fog and scarcely distinguishable from Eder reservoir. Three aircraft went in. The first breached the dam; the release mechanism of the second plane failed, and the aircraft was destroyed by the explosion of the mine as, still attached to the plane, it grazed the parapet of the dam; the third mine made a second breach, punching a hole in the wall about thirty feet below the parapet but leaving the top of the dam intact, a bridge across the cavity.

Finally a third dam, the Sorpe Dam was breached. As the attackers left it the valley "seemed to be deep in water".

Reconnaissance with cameras completely confirmed the crews' reports. On May 17, the day after the attack, a photograph showed that the breach in the Mohne dam was now about 250 feet wide at the crown of the dam and about 130 feet at the base. Water was still pouring through the gap. Next day it was seen that the breach extended to the very foundations of the dam, and the reservoir was now almost empty. Below the dam the floods extended to a great distance, and industrial and other damage was obvious. At Froendenburg a power station, rail and road bridges, sidings and a factory were under water. Elsewhere, between Schwerte and Hattingen, many factory yards were under water, and in this district the floods took a long while to subside. The railway viaduct near Herdecke, which carried the main line between Dortmund and Hagen, was fractured.

On May 18 the Eder dam had a breach 180 feet wide at the crown and 100 feet wide at the base. Water was still pouring through two days after the attack, when seven-eighths of the contents of the reservoir had flooded away. Flood damage had extended to a great distance; sixteen miles from the dam the whole area between Wabern and Felsberg was under water. A whole airfield at Fritzlar was submerged and many huts on it had been demolished. In the large and important town of Kassell large areas were flooded.

According to official German records, a hundred thousand workers engaged on vital war work were put out of action by this single raid.

Such were the results of this raid, which proved beyond a peradventure that air power was now a decisive strategic method of waging war. The road to Hiroshima and Nagasaki was open. Science coupled with great skill and great bravery of the aircrews had opened that road.

Novelty at the Physical Society Exhibition

At the 35th annual exhibition of the Physical Society this year there were several new features not yet known to the commercial world, which is more in keeping with the

Society's rule (which is not always applied) that exhibits shall be new apparatus.

The first group of such devices deserve the comment: Why was this not thought of or produced before? For example, there is a very simple development in the dials of instruments, such as voltmeters, produced by Nalder Bros. & Thompson Ltd. Everyone using a dial instrument meets normally with an irritating difficulty in making a precise reading. The needle swings over the figures and is an eighth of an inch or so above them. The result is the possibility of parallax error (the error caused by the observation of two things when one is behind the other), for a slight move of the observer's head to one side makes the nearer thing (the needle) appear opposite a mark on the scale that is not the correct reading. Great care has, therefore, to be taken to make sure that the eye is vertically over the needle. At the same time the needle must, for accuracy's sake, be very narrow. In many of the newer instruments a simple change has been made. The periphery that carries the scale is raised above the surface of the face or dial. The needle is then made of just the right length to reach to the inner edge of the raised periphery and is at the same level. The coincidence of needle point and scale mark is thus perfect and gives no error according to the position of the observer's eye. Many man-hours will be saved in the control rooms of industrial firms by this simple change.

Somewhat in the same class comes the development of unusual elements like molybdenum, tantalum and zirconium. The last of these has now been in commercial production by Murex Ltd. for some months—the first such production in Great Britain. Yet zirconium was first isolated in 1824 by Berzelius, and it is far more abundant on the earth than copper or lead or zinc. Why, then, was it not in production in Great Britain until 1950? The answer rests on a number of factors, the most important of which is that when zirconium is prepared by normal chemical methods it contains oxides and nitrides made by the reaction of the hot metal with oxygen and nitrogen, and these oxides and nitrides make the metal far too brittle to fabricate. So success in the production of zirconium has advanced with the production of high-temperature vacuum techniques on a commercial scale. The zirconium thus produced is exceedingly inert, being for most purposes non-corrodible even by concentrated acid. It can be made into wire and rod and sheet, and it can be spun to make crucibles. It has the peculiar property that human flesh will grow closely to it, so it is very useful for metal splints and inserts in bones. It has less than a third the density of platinum and less than a half the density of tantalum. So, though still expensive, bulk for bulk it is more economical than tantalum and it is cheaper than platinum. Its price at present ranges from about ten shillings an ounce for rod to perhaps fifteen shillings an ounce for sheet. It can be alloyed to some other metals. The three main applications, it is expected, will be for electrodes in electronic devices, for surgical splints and the like, and for industrial chemical plant.

Of the striking instrumental achievements, apart from radar devices, monitoring and control mechanisms and the like (all of which show steady progress in reliability, ease of handling, and the information displayed) is the camera developed by the Ministry of Supply Armament Research Establishment. This camera is designed to take 400,000 photographs a second; each photograph is some two inches in diameter and each gives a high level of detail discrimination. The film on which the photographs are taken is mounted round the inner wall of a cylinder some 51 inches in diameter and a foot or so deep. A central cylinder contains many very small lenses succeeding each other round the wall. On the axis a compressed-air motor rotates at 150,000 revolutions a minute. The light from the object enters a lens system projecting through the wall of the outer cylinder. This light then passes through polaroid, a Kerr cell, and another piece of polaroid. This whole unit constitutes a shutter. The first piece of polaroid polarises the incoming light. That is to say, it allows through only light vibrating in one plane. The second piece of polaroid has its axis at right angles to that of the first piece. The effect is thus to cut out all light because the second piece of polaroid allows light through only in one plane, just like the first piece, but the orientation means that the plane of vibration allowed by the second piece is at right angles to that passed by the first piece. In other words, the polaroid pieces are 'crossed'. When a large voltage is applied to the Kerr cell, however, the plane of polarisation of the light passing through it is rotated so that it *can* pass through the second piece. (The Kerr cell is merely a glass or silica vessel containing a suitable fluid and having two electrodes in it, one at each side of the cell. When a voltage is applied to the electrodes the plane of polarisation of any light passing through the cell is rotated. This is known as the *Kerr effect*.) The voltage is applied very sharply. This is achieved by a specially designed amplifier. Thus a sudden voltage lets light through the shutter system for the length of time required for an exposure, namely, a tenth of a millionth of a second (0·1 microsecond). The signal to operate the shutter is generated by a separate source of light just outside the inner cylinder. This light is reflected from a plane mirror fixed to the shaft of the motor. On the inner surface of the inner cylinder is an array of polished facets at just the correct angle to send the light back along its own path to the mirror and thence back towards the source but on to a half-silvered mirror that reflects it on to a photocell. This converts the light into electricity, which is then amplified and shaped to make a vertically fronted square pulse of some 16,000 volts. It is this pulse that effects the shuttering. The timing is arranged by the speed of the motor and the number of reflecting facets in such a way that the shutter operates just at the moment when the incoming light (from the object) is reflected from the rotating mirror towards one of the tiny lenses. It lasts for the exposure time and then triggers off. Thus a succession of pictures is made on the film. The aperture of the camera is very small—*f/50* or thereabouts—and so the light admitted in 0·1 microsecond is very small. Thus the camera is only suitable for use with powerful sources such as explosions, for the photography of and analysis of which the camera has been designed. It is hoped that an aperture up to *f/16* can be achieved eventually to increase the scope of the instrument. It was not in use at the exhibition because space was very limited and the bottles of compressed air would have filled it. But all the separate sequences have been tested and there seems no doubt that the camera will shortly be in use. With such a speed of operation, details of the progress of explosion flames (and

of lightning as well if the coincidence should happen that a lightning flash occurred in the right direction just when the camera was operating) can be obtained in a permanent form.

The interesting exhibit by the Colour Group of the Physical Society was designed to show in a series of demonstrations the history of the study of colour vision. This popular exhibit received much attention, especially in the original apparatus of pioneers like Rayleigh and Maxwell, and the demonstrations of original experiments carried out by Boyle and Newton as well as by their modern descendants.

Perhaps the most significant trend of all was shown in three of the Ferranti exhibits. This trend is the conversion into quantitative electrical and electronic operations of what have up to recently been considered exclusively 'mental' events. There were three pieces of apparatus, two of them being alternative arrangements of the same development. The simplest of all is the 'judgment box'. (Naturally, this and the other two exhibits provided entertainment of an unusual kind.) It shows a panel on which are mounted twenty-one knobs, an instrument dial, and some switches. Twenty of the knobs are in two rows of ten each. Each knob of the upper row is connected to its counterpart in the row below. There are thus ten independent pairs. The upper row of knobs control the 'weights' (estimates of importance) to be given to a judgment or rating, while the lower row control control the 'weights' to be given to the factors entering into the judgment. For example, a manager might be interviewing candidates for a particular job. He decides on ten independent factors—willingness, skill with figures, and so on—relevant to that job. Each has more or less importance, and he sets the factor controls (the knobs in the lower row) to values he decides, six steps being available—0, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, 1. Then he interviews the first candidate and sets the controls for weighting judgment according to the candidate's rating in each of the factors, in one of five different, positions— -2, -1, 0, $+1$, $+2$. Each such setting is multiplied automatically by the factor-weighting and the whole added up algebraically (i.e. taking account of positive and negative values) to give the final judgment 'for' or 'against', the result being shown on a centre-zero instrument. If there is indecision and the needle remains in the centre, it may be due to lack of sensitivity, the bias on one side not being enough to move the needle. In this case, if a decision is urgently needed, there is an 'urgency' knob that can be used to increase the sensitivity.

The theory of this extraordinary box of tricks is very simple. All that one knob of a pair does is to select voltages (-2 volts, -1 volt, 0, $+1$ volt, $+2$ volts) and the selected voltage goes to a potential divider that takes 0, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, of the whole of the voltage applied. The algebraic summation of the voltages gives the over-all decision.

The sort of problem given as an example is not the only one. For example, a problem to be decided might be whether a further increase of pay would be important for increased production. The opinions of the people, ranging from the managing-director to the office-boy, are collected, let us say. The value of the managing-director's opinion will clearly have to be $+2$ on this scale, whereas that of the office-boy may be as little as -2. Each of the ten gives an opinion on the factor and the opinion is selected for one of the six values on the lower knob corresponding to the person giving the opinion. The decision would then show the resultant opinion 'yes' or 'no', for or against an increase of pay in this instance.

The most fascinating exhibit of the whole show, however, consisted of the other two 'mental devices' of Ferranti. They were both variations of the 'logical computer'. The entertaining question asked of one machine was: "It is known that salesmen always tell the truth and engineers always tell lies. B and E are salesmen. C states that D is an engineer. A declares that B affirms that C asserts that D says that E insists that F denies that G is a salesman. If A is an engineer, how many engineers are there?" Anyone giving careful attention to this question will soon find that it is built on seven variables, each of which has only 2 possible states, e.g. A is an engineer; A is not an engineer. The second long sentence shows that there is also a relationship 'or else'. For instance, G is or is not a salesman. If he is, F is lying. So he is an engineer. But if G is not a salesman, F is being correct and so is a salesman. Thus the statement comes to A or else B or else C or else D or else E or else F or else G is an engineer. The top panel of the instrument has one label per variable and three lights, one mauve, one green, one red. When the green light is on the variable is agreeing with the statement corresponding to the variable. When the red light is on the variable is not agreeing with the statement. When the mauve light is on, the variable is not obeying the rule. The rules are interposed between the variables and the output by means of 'rule' boxes, consisting essentially of relays. One rule is 'not'. The other rule is 'or else'. The rule 'is' is implicit in the initial set-up. The seven statements set up are: "A is an engineer, B is an engineer, C is an engineer", etc. Only one positive statement agreeing with this is given in the data. So variable A is joined directly to the output. B is joined to a rule box 'not' and thence to the output because the data gives this. E is similarly joined. A and B and C, etc., are joined by 'or else' rule boxes with one end to the output. The machine is now set in motion and a motor turns a selector that combines all the possible statements together seven at a time, the groups coming in succession. While there is a single rule not being obeyed the selector goes on rotating. As soon as all the rules are simultaneously obeyed, all the outputs lock and the selector stops, showing the green lights on the panel to give the ones that are in agreement with the statements set up. But this is not the only possible answer. So the selector is started again and it goes on until another solution is obtained. The procedure is repeated until the first solution is repeated. Then it is known that all possible solutions have been found. In the example, there are four solutions, each giving the same quantitative answer namely, three engineers.

The skill of using the device is in analysing the problem and connecting up the rule boxes. The second device shown was a variant in which all the possible solutions are not found. Instead the first answer is arrived at. The rules are more, such as 'if and only if', 'if then', etc. The first of the devices could be compared to the careful theoretical scientist while the second is the impatient practical scientist who wants an answer as quickly as possible.

Many people will dislike such devices. But they are more important than their entertaining use (and the use of the

Nimrod machine made by the same firm for the Science Exhibition of the Festival of Britain) at the exhibition indicate. Their possible use in problem-solving is clear when the variables are limited. In addition, their use as analogies for the operations of thought is obvious. It is easily seen, for instance, that one process of thought is merely the elimination of alternatives one at a time.

The House Longhorn Beetle

On the Continent one of the most destructive insect pests is the House Longhorn Beetle, *Hylotrupes bajulus*. This insect is from a half to one inch long and is black, with two transverse bands of grey hairs on the wing covers. It can be identified by the presence of two smooth, shiny black prominences on the first body section.

Its appearance in certain localised areas, chiefly Surrey, has directed attention to this beetle which was formerly regarded as unimportant in Britain. Though there is as yet no reason to fear that this beetle will become a menace to property owners throughout the country, the Forest Products Research Laboratory is endeavouring to trace all cases of infestation in order that effective control measures may be introduced before any extensive outbreak of the pest can occur. It is in the interests of property owners that early action should be taken to deal with infested buildings before the damage becomes extensive. Replacement of the timber attacked may be a costly operation, since it may involve stripping roof coverings in order to reach rafters, ceiling joists or other affected timbers.

The beetle attacks only seasoned softwoods, chiefly structural timbers in buildings and sometimes fencing. The damage is generally confined to the sapwood, but occasionally the heartwood is also involved. In buildings the beetles usually make for the structural timbers of the roof and attic floors and gradually work their way downwards.

The eggs are laid in cracks and crevices in timber. Each female lays from 20 to 200 eggs and the larvae, which emerge after ten to fourteen days, soon start to bore their way into the timber. After feeding for several years, during which they do considerable damage, the larvae reach their full size, pass through a resting stage lasting about three weeks, and finally change into beetles. During warm periods in June, July, and August, the beetles emerge from the wood through broadly oval holes ranging in diameter from $\frac{1}{8}$ in. to $\frac{3}{8}$ in. The whole period of development from egg to beetle takes from three to eleven or more years, depending on the condition of the timber in which the larvae are feeding.

The tunnels excavated by the larvae in the sapwood are packed with wood powder and excrement. At first they usually run just under the surface of the wood. At a later stage they penetrate more deeply, and may enter the heartwood. No wood dust is expelled from the tunnels. Infestation, therefore, tends to be difficult to detect, especially if the beetles' exit-holes are few in number. Sometimes, blister-like swellings on the surface of the wood are the only visible indication of the extensive tunnelling within. Timbers suspected of being infested should be tested by probing with a knife blade or spike. Attention has sometimes been directed to the presence of the pest by the noise made by beetles biting their way out of the woodwork during the summer months. In so doing they will perforate lead and other roofing materials which hinder their escape.

Control measures consist mainly in cutting out infested sapwood and treating the remainder with a liquid insecticide. Fumigation is seldom practicable on a large scale for the disinfestation of dwelling houses in built-up areas, nor are all types of buildings suitable for fumigation. When attack by this beetle is suspected, a sample of the infested wood should be sent to the Forest Products Research Laboratory to confirm the identity of the insect and for advice as to the best method of treatment.

During the past fifty or sixty years the House Longhorn Beetle has become a very serious pest in several Continental countries. In Denmark it has become so widespread and causes such extensive damage that many companies undertake the insurance of buildings against infestation. Before the war it was compulsory in two districts of North Germany for all buildings to be insured against damage by fire and this beetle. An official survey made in 1938 showed that House Longhorn Beetles were present in the attics of about 40% of all German houses. In Stockholm, 195 of 340 houses investigated were found to be infested.

One theory put forward on the Continent to account for the emergence of what was formerly an uncommon insect as a pest of national concern is the change in the type of roof covering from thatch, wood or porous red tiles to sheet metal, slates, black glazed tiles and black roofing felt. It has been pointed out that the effect of this change-over has been to raise the average temperature of the roof space, which may have assisted the rate of development and spread of the insect.

In Britain the House Longhorn Beetle has long been known to entomologists, and there are records of its collection here as far back as 1795. It is only within the past fifteen years, however, that it has come to be regarded as an important timber pest. The first case of serious infestation was discovered at Walton-on-Thames in the roof of a house examined by the Forest Products Research Laboratory in 1933. This building was about 24 years old, and it was impossible to determine whether the beetles were present in the timbers when it was erected, or whether infestation took place at a later date.

Since 1933, numerous cases of active infestation have been discovered, chiefly in Surrey. Apart from one or two cases reported from Leicester and York, practically all occurrences have been confined to a few small areas south of London.

A possible explanation for the comparatively sudden transformation in Britain of an apparently inoffensive insect into a destructive pest may be deterioration in the quality of the timber used for roofing. Before the war most roofing timber contained a large proportion of heartwood, and the damage the beetle could do was insignificant. Now younger trees with a higher proportion of sapwood are being used for structural purposes, so that the ravages of the insect are no longer confined mainly to the edges of the timber.

No reliable conclusions can as yet be drawn as to the origin of attacks and the manner in which they spread, but indications are that direct infestation from house to house takes place during the flight of the beetles in the summer months. It is perhaps significant that the insect has sometimes been found in imported packing cases. So far there is no evidence that the apparent extension of infestation is due

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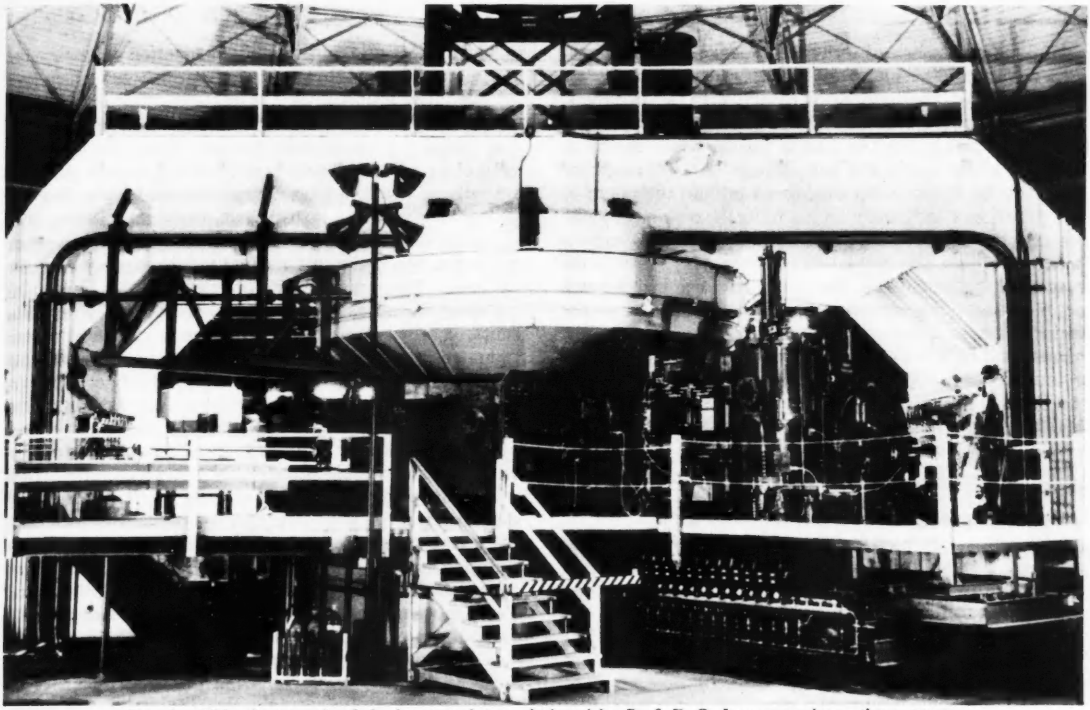

FIG. 1.—This photograph of the latest cyclotron designed by Prof. E. O. Lawrence shows the vacuum pumps (on right), which evacuate air from the cyclotron tank wherein the atomic particles are accelerated. This cyclotron with its 4000-ton electro-magnet stands on Charter Hill.

The Progress of High Vacuum

Prof. E. N. da C. ANDRADE, F.R.S.

THE Latin word *vacuus* means empty and vacuum an empty space, which seems simple, but we are at once confronted by the question as to what we mean by *empty*. If we mean a space in which there are no atoms of matter, then we have never known a vacuum in our laboratories and probably never shall, for if we consider a litre flask, which has been exhausted of its air by the most modern methods, it still contains not millions of atoms but millions of millions of atoms—about a thousand each for everyone alive on earth. However, before it was pumped out it contained ten thousand million times as many atoms. It is clear, then, that we would do better not to talk of emptiness or of number of atoms, but rather to consider the fraction of atmospheric pressure that prevails in an exhausted vessel. In general, when we speak of high vacuum we mean a pressure of not more than a hundred thousandth of atmospheric pressure and some people would say a millionth of an atmosphere or less. It is difficult to measure very low pressures with certainty, but the highest vacuum produced is probably about a ten thousand millionth of an atmosphere. According to Vassy the pressure in interstellar space is estimated as about a ten thousand millionth of this.

The pressure of a normal atmosphere is represented by a barometric height of about 760 mm. of mercury and the mm. of mercury is now called a *tor* (or *torr*) after Torricelli. If we imagine the barometric height magnified until it is as tall as Everest, then 1 mm. (or 1 tor) will, on that scale, be about as high as an average theatre and a ten thousandth of a mm., which is an ordinary decent vacuum, will be represented by the thickness of a sixpence. The pressure in the best vacuum we can produce will be represented by about a 25th of the thickness of a cigarette paper.

Now the development of the vacuum pump as we know it today is a matter within the memory of men still in full vigour. From the first invention of the vacuum pump by Guericke until the early years of the present century the principle on which the ordinary vacuum pump was made was much the same: it consisted of a cylinder with a tightly fitting piston and suitable valves, so that on the withdrawal of the piston air was sucked out and on the return of the piston expelled, the exhausting vessel being cut off during the return stroke. There were, of course, many improvements in construction: the introduction by Robert Boyle (or probably by Papin, working under Boyle) of two cylinders, so that the pressure of the outside

air on one piston helped to withdraw the other was a distinct advance. The pump made by Francis Hauksbee at the beginning of the eighteenth century, with two cylinders, the pistons being worked by a pinion wheel between racks, was long a pattern: in fact pumps very similar were being made up to the end of the last century. An improvement was made by Fleuss, who introduced oil into the pump so that the air was completely displaced by the piston, and who realised the importance of using an oil of low vapour pressure. This is an essential point: if there is present in the evacuated space a liquid that vaporises the pressure will not fall below the vapour pressure of that liquid at the temperature in question. Geryk pumps, which was the name given by Fleuss to his pumps, were extensively used in the early days of the electric lamp industry for exhausting the bulbs: the pressures produced were ordinarily as low as 0·02 mm. of mercury. Cylinder pumps for high vacuum are now things of the past.

Rotary Air Pumps

These cylinder pumps were mechanical pumps, that is, pumps which depended for their action on precision workmanship. The pumps used for the very highest vacua today are not of this kind, as I shall soon describe, but there is a class of mechanical pump very widely used today, the rotary pump. As the word implies, these pumps do not work by an up and down motion, like the cylinder pump, but by a steady rotation. Nevertheless, as in all mechanical pumps, a space is alternately increased and decreased. The ancestor of them all was Prince Rupert's water bolt, intended for use as a water pump.

The modern rotary air pumps are a development of the last forty years or so. In the 1890s the pioneering work of J. J. Thomson, Lenard, Crookes and the other early heroes of vacuum physics was carried out by pumps of quite a different type, in which the air was drawn out by a falling mercury column, the evacuated space being cut off during the rise of the column. Typical is the Toepler pump. These pumps were very slow: it took a morning and some skill to evacuate a tube as well as can be done by one of these small rotary pumps in a few minutes, without any skill.

Later Gaede, the single man who has done most for the modern mercury pump, invented a way in which the mercury could be made to displace the air by continuous rotation. In 1910 to have such a pump was the ambition of every vacuum worker. Another type of pump, the so-called molecular pump, working on a new principle, was later invented by Gaede. It demanded very high mechanical precision in its construction and was never much used, for during the First World War a completely new type of pump was introduced which today dominates the high vacuum field.

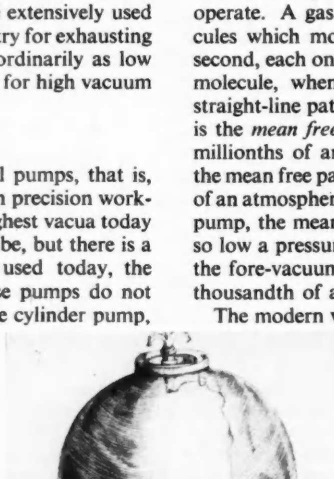

FIG. 2.—Boyle's Air Pump. (*See* the articles on Boyle, DISCOVERY, December 1950 and April 1951).

This type of pump, for which I suggested some time ago the name 'Vapour-Stream' pump, which has since been adopted by Dushman, is like certain other high vacuum pumps, such as the molecular pumps which I have just mentioned, in that it will not start pumping unless the pressure is already fairly low: it is like, say, a plane for smoothing wood, which cannot be used on a log, but demands a surface already sawn fairly smooth, or like a film star who cannot produce her effect unless the atmosphere has been suitably prepared before—by manipulation of gas. The preliminary lowering of the pressure is necessary because the mean free path of the gas molecules must be fairly large before the vapour stream pump can operate. A gas consists of an immense number of molecules which move with speeds of hundreds of yards per second, each on a straight line until it collides with another molecule, when it turns aside and carries out another straight-line path. The average distance between collisions is the *mean free path*: at atmospheric pressure it is a few millionths of an inch, but naturally as the pressure falls the mean free path increases and at a pressure of a millionth of an atmosphere, which is easily reached with a mechanical pump, the mean free path will be measured in inches, but so low a pressure is not needed for what the Germans call the fore-vacuum: a pressure of 0·015 mm., that is, a fifty thousandth of an atmosphere, is often used.

The modern vapour stream pump depends upon the gas to be removed diffusing into a stream of rapidly rushing vapour molecules which carry it along: the vapour is condensed on a cooled surface and so does not flow back against the entering gas. The vapour originally used was mercury: a trap cooled by liquid air is always inserted between the pump and the space to be evacuated, to condense the vapour of the mercury, which has a pressure of one or two thousandths of a millimetre at room temperatures. Today a variety of oils and other organic liquids, such as butyl phthalate, with very low vapour pressure at ordinary temperatures, are used. The vapour pressure of Apiezon B oil is, for instance, 10^{-7} tor. During the last few years compounds called silicones have been used in vapour pumps—they may be familiar to you as cyclic and linear methyl polysiloxanes.

These vapour pumps exist in a very great variety of designs. Often one pump helps to produce the fore-vacuum for another and we talk of two-stage or three-stage pumps. Great care and ingenuity has been spent on the design of the nozzle. But what I want you to notice about all these vapour stream pumps is that there are no mechanical moving parts and no precision machining. The advantage of this from the point of manufacture and maintenance need hardly be stressed.

Now that we have considered rapidly how high vacua can be readily produced,

let us consider why it is so important in modern research. In practically all branches of physics and in many aspects of chemistry and other sciences we are concerned with flying particles, which may be ultimate particles, such as electrons or protons, but which may also be atoms and molecules. Whatever they are, collisions with the molecules of air or any other gas soon reduce their speed in a given direction, so that instead of travelling swiftly forward, they are buffeted about in all directions, until they become merely one of the molecular herd. Removing the air molecules from their path gives them a greater straight line run: the higher the vacuum, the fewer the collisions. Thus, the beam of electrons in a cathode ray tube would travel a minute fraction of a millimetre in air at atmospheric pressure, but flies freely across the tube in which a high vacuum exists. In all the valves used in high frequency circuits and amplifiers a high vacuum has to exist to give the electrons free run. In X-ray tubes the rays are generated by a swift beam of electrons striking a metal plate: to give the electrons a free run a high vacuum must exist in the tube and in most tubes nowadays there is a vacuum pump running all the time, to deal with any gases liberated, although sealed off tubes are employed for some purposes. Electron diffraction apparatus, electron microscopes, all electron beam apparatus needs high vacuum. The mass spectrographs which established the existence of isotopes need high vacuum to give charged atoms a free run of feet. And, to take a subject much in the public eye, plant for using atomic fission to make material for atomic bombs needs high vacua. All atomic accelerators, such as cyclotrons, in which atoms are speeded up until they have a speed nearly that of light, corresponding to millions of volts, need very high vacua, since collisions would slow down the atomic projectiles.

One immense field of use is, then, simply to take obstacles out of the way of flying particles. Sometimes, however, our main concern is to make it easy for atoms to leave a surface. If we have a liquid surface atoms are leaving it all the time—evaporation—but a large number of them strike air molecules and return to the surface. If we remove the obstructing air molecules the evaporation takes place much more freely, and since the more energetic molecules fly off more rapidly than the slower ones the liquid cools down. Further, since quite slow molecules can get away when there is no obstacle, we can have free evaporation at quite low temperatures. Different aspects of this process are vacuum distillation and rapid drying at low temperatures, which I shall briefly discuss later.

Another aspect is when the fate of the atoms is what interests us. If metal is heated in a very high vacuum it evaporates freely and the molecules fly off without obstacle and will deposit on any surface opposite. This vacuum coating is another aspect of vacuum to which I shall refer.

The high vacuum pump is, then, an indispensable tool in the research laboratory and the experiments that furnished our whole knowledge of atomic physics are bound up with the production of high vacua. This could have been said with equal force thirty years ago, and thirty years ago all the types of pump that I have described had already been produced in principle, although many improvements in design have since been devised. The remarkable feature of the last thirty years to which I wish to direct your attention is, however, the immense increase in size of vacuum pumps and the striking applications that they have found in

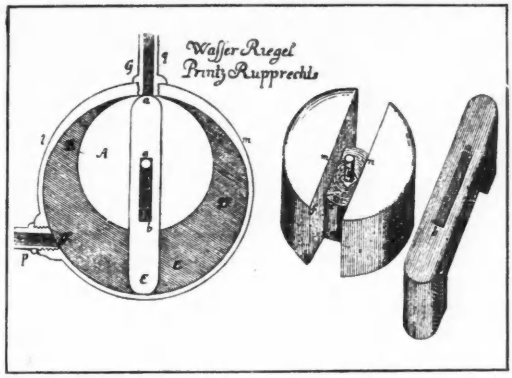

FIG. 3.—Prince Rupert's "Water-Bolt", a seventeenth-century pump intended for pumping water.

scientific industry. This period, since the end of the First World War, has seen laboratory method and techniques in many fields adapted, with little alteration, to large-scale production. The electric discharge lamp, the 'wireless' valve, the cathode ray discharge tubes of what is called the light electrical industry (as distinct from the heavy electric industry, that deals with dynamos, motors, power supply in general and so on) are creations of the laboratory that, with immense ingenuity—sometimes genius—are produced on a commercial scale: the manufacture of modern drugs and biological preparations of all kinds is the organic chemistry of the laboratory immensely enlarged but not essentially changed. In the same way today high vacuum, as known in the laboratory, has become almost a branch of light engineering. I want to say something of this immense increase in scale and of the application of laboratory processes to industrial ends.

The first application that I will consider as most obviously a development of the research laboratory, is large-scale atomic research. In cyclotrons, betatrons, linear accelerators and such-like elegant constructions which take the place of the artistic marvels of other ages—I suppose that a large cyclotron is our version of Michelangelo's *Moses* and a betatron is our Donatello's *David*—we are dealing with flying particles which have to travel great distances (sometimes miles or tens of miles) without serious collision effects. The first of these large-scale atomic accelerators was the 300,000 volt apparatus of Cockcroft and Walton, for which one oil vapour pump with a speed of about 300 litres per second sufficed. There are few details available of the three thousand million electron-volt accelerator now being planned at the Brookhaven National Laboratory, New York, but we know that the pressure in the chamber must not exceed 1/100,000 tor and that this will demand twelve or more pumping stations each consisting of a 20-inch oil diffusion pump suitably backed, the speed will be about 2500 litres per second for each pump, or each pump more than eight times as rapid as Cockcroft and Walton's. High vacuum pumps were also an essential part of the development of the atomic bomb: in particular, for the separation of U 235 by gaseous diffusion, "since much of the separation was carried out at low pressure, problems of vacuum technique arose, and on a previously

unheard-of scale" says H. D. Smyth. Few details have been published, but an article has appeared on the development of techniques for leak detection: this technique was one of the major engineering problems, and we read of the vacuum testing *crews*—groups of experts employed entirely on detecting the leakage problems. This may give you an idea of the complexity of atom bomb making. The electromagnetic separation of isotopes also made heavy demands on large-scale vacuum technique.

This use of vacuum pumps is a large-scale version of their familiar use in the lamp factory and in the laboratory, the object being the removal of as much air and vapour as possible from the space to be evacuated. Let us now turn to the use of high vacuum for special purposes developed in the last few decades and take first the deposition of thin metal coatings on solid surfaces. This is done by having in the evacuated space a metal so hot that it evaporates at an appreciable rate: in a space where there are relatively few atomic obstacles the metal atoms fly from the surface in straight lines and adhere to any surface put in their way. At one end of the scale, the very small end, we have the use of the method for making minute detail visible in the electron microscope. This form of microscope, as you know, possesses great resolving power—that is, it will distinguish detail as small as a ten millionth of an inch, or a ten thousandth of the thickness of a cigarette paper. The trouble is that the biological preparations so often under investigation are built up of light atoms—carbon, hydrogen, oxygen and such-like—and scatter the electrons very little, so that there is insufficient contrast, just as there is little contrast in a faded photograph. One way of getting round this difficulty is to send a beam of heavy atoms obliquely into the specimen to be examined: then, just as the setting sun throws ruts and hillocks into contrast, by producing strong shadows, so do the heavy atoms deposit on surfaces turned towards the stream and not on those away from it, and show up in detail. This process is known as metal shadowing. Let us consider gold shadowing as typical. A little gold is put on a coil of tungsten wire, which is heated white hot by an electric current. If the vacuum is high enough—the pressure ought not to exceed a ten-thousandth of a millimetre—the gold atoms fly in a straight line and deposit on the aspects of the preparation that face the source and not on the shielded regions.

Pure palladium, chromium and other metals are often used in place of gold or gold-palladium alloy. At the other, the large end, of the scale we have the use of vacuum coating for silvering—or rather, since silver is not used, for metallising—the surface of mirrors—astronomical mirrors, in fact all mirrors used for accurate scientific work, are, of course, silvered on the front of the glass, so as to have only one reflecting surface: the metal coating must therefore be bright and smooth on the upper face. Luckily aluminium, vaporised in vacuo, deposits on glass as a polished film that needs no burnishing and remains bright for years. The glass surface is placed in a large vacuum vessel and the aluminium is vaporised from helices of tungsten wire, on to which the molten aluminium metal hangs by surface tension. For large mirrors several sources are used, and the pressure is such that the mean free path is 100 inches or so. The 200-inch mirror of the great reflecting telescope of Mount Palomar has been aluminised in vacuo: so has the 100-inch mirror of the telescope at Mount Wilson, which was originally silvered, and so has a 60-inch mirror, as well, of course, as numberless small mirrors. Sometimes the metal is vaporised from a crucible.

The applications of the vacuum coating process cover a very wide field: for instance, nowadays condensers, instead of being made of sheets of foil separated by paper, are made of paper or cellophane on which a very thin coating of zinc or aluminium has been vacuum-deposited. This simplifies the process of rolling the condenser plates into a cylinder and reduces the size to less than half. Coloured filters of the new interference film type are also made in a similar way. The process can be used for deposition thin layers of other substances than metals, for instance, films of quartz on prisms of rock salt and such-like, to protect them from attack by moisture, or films of magnesium fluoride of controlled thickness on lens surfaces, to reduce reflection—the so-called 'blooming' process. The powdered fluoride, for example, is heated electrically in a high vacuum and condenses as a hard, very thin glassy film on the cold glass surface opposite to it. In general the process has the great advantage that the surface is not heated and that the thickness is easily controlled. A less scientific use of vacuum coating is the preparation of those silvery dress ornaments which are made of plastic, on which a very thin layer of metal is deposited. Ordinary electro-plating cannot, of course, be used for non-conducting plastic.

Another use of large-scale high vacuum is when the evaporating substance is not a hot metal, but a liquid. When a liquid vaporises the faster molecules at the surface fly off, but in the ordinary way most of them rebound on hitting air molecules and return to the surface. If there is a high vacuum above the surface all the swift molecules fly off, with a double result; firstly, that the liquid evaporates very rapidly and secondly that it cools markedly. For instance, mercury, which boils at 356°C. at atmospheric pressure, boils at about 150°C. at 3 tor pressure: water under low enough pressure can be made to boil rapidly at 0°C. and to freeze.

We will come back to this freezing and evaporating at freezing-point: for the moment let us consider the application of the rapid boiling at high vacuum which is called vacuum distillation. In 1928 C. R. Burch found that under a vacuum so low that nearly all the molecules of the vapour hit the walls of the still direct, instead of colliding with air molecules, he could boil off from certain high boiling petroleum products all the more easily vaporised fractions, leaving an oil which, at atmospheric temperature, had practically no vapour pressure. It was on this simple line of reasoning that the famous Apiezon* oils and greases were prepared. Distillation in a high vacuum means a low temperature which does not affect bodies prone to thermal decomposition. Since Burch's early work vacuum distillation has been used for a wide variety of purposes, such as the separation and concentration of substances contained in animal fats and oils, and of organic compounds of high molecular weight and relatively unstable structure in general, such as sterols and vitamins. The separation of vitamin A from cod-liver oil and of setosterol from vegetable oils are examples.

Let us return to the use of high vacuum for producing evaporation at low temperatures, when what we are concerned with is not the molecules that escape but the

* From the Greek *A* without, and Piezein, to press.

substance left behind. This gives us a way of drying rapidly without raising—indeed, often with great lowering—of the temperature. Let us take first food products as an example. In America orange juice is in great demand: it is clearly wasteful to ship water over long distances if a dry powder can be produced which can be reconstituted to reasonable orange juice by the addition of water. Concentrating the juice by boiling gives, apparently, an unsatisfactory product. The process now used is to evaporate the juice rapidly at 50° under low pressure: this produces, it is said, a powder which, on the addition of water, makes excellent juice. Readily reconstituted milk and coffee powders are made similarly and they say that oysters have been treated in the same way. More important and more striking is the drying of blood plasma and serum, with storage for transfusion purposes in view. Clearly in a large hospital where blood may be required at any moment it is desirable to store it, but even if liquid blood, as drawn from the donor, be kept at the low temperature of 5° C., changes take place in it—*Blut ist ein ganz besonderer Saft*. With blood and serum the pressure is lowered to such an extent that the rapid evaporation leads to freezing: the actual drying then takes place by the evaporation of moisture from the ice. This process is known as freeze-drying and is by far the best method of concentrating labile substances, that is, substances easily decomposed by heating. It may seem strange to some of you that ice evaporates, but it has, at 0° C., a vapour pressure of just over 4·5 mm., which is a full quarter of the vapour pressure of water in a warm living-room, so that with the same surface it will evaporate a quarter as fast as water at 70° F. The only disadvantage is that the rapid evaporation before the freezing has had time to take place leads to excessive foaming. This can, of course, be avoided by freezing the produce by ordinary cooling methods before the vacuum is produced, but there is another method recently developed which avoids this complication. Open vessels containing the liquid are held in a stand which rotates rapidly, with the result that, owing to centrifugal force, the liquid is spread out in a thin layer on the side of the vessel furthest from the axes. This gives a large liquid surface and a small liquid depth, which leads to rapid evaporation without foaming. The final product is left in a porous, spongy state which makes it easy to reconstitute it by adding water. The absence of air means that no oxidation can take place and the low temperature that chemical bacterial change is eliminated.

The freeze-drying process is used on a large scale for a variety of processes. The preparation of dried blood, which is stored in large glass jars, is only one example. In the manufacture of penicillin and other antibiotics freeze-drying is used in the final stages. Other examples are the drying of antitoxins, bacterial cultures and vaccines and of certain proteins.

Metallurgy is another field into which laboratory high vacuum has penetrated. Most metals as prepared under ordinary conditions contain dissolved gases. If the metal be melted in a high vacuum these gases escape and further, the total quantity of gas that can be removed from ordinary metals by heating in vacuo is between 1 and 20 $cm.^3$ per gm. of metal. Some years ago the vacuum melting of metals was a laboratory matter: today charges weighing hundreds of pounds are cast in the high vacuum that was once the prerogative of the laboratory.

There is today, I feel, a tendency to decry the importance of pure research, to say that what our country requires is more and more scientific effort for the application of discoveries to industry and for the development of processes and inventions based on scientific discoveries. Of the importance of applied science for our national well-being no responsible man is in doubt: that our country cannot survive as a first-class power without it is certain. It was in the personnel, equipment and direction of our industrial laboratories that we were, generally speaking, behind Germany and America before the war. But in order to apply prime discoveries you must have prime discoveries to apply. What we require in science, as in everything else, is sanity and a just balance, and I fear that today the importance of pure research is in danger of being under-estimated. The story I have told is the most intricate blend of pure research in university laboratories, the work of the independent inventor and the indispensable manufacturing development in the workshop of enterprising firms. The work of J. J. Thomson and the Cavendish school in general, of Lenard, Wien and the continental school of vacuum physicists, of the Danish mathematical physicist Knudsen, of the German inventive genius Gaede, of brilliant Irvine Langmuir of the research laboratory of the American General Electrical Company, of Cecil Burch, a lone wolf who has worked both in industrial and university laboratory, and of the great manufacturers are all represented in the story. It has needed the combined efforts of pure and applied science and of engineering to reach the apparently trivial ambition of the high vacuum specialist—to produce nothing at all shut up in a jar.

PROGRESS OF SCIENCE—*continued from p. 172.*

to the use of timber containing the larvae, nor is there any record of the occurrence of the living beetle, or its grubs in building timber imported from the Baltic countries or from Germany. It is considered desirable, however, that care be taken to avoid the importation of building timber infested with this pest.

In view of the serious damage which the House Longhorn Beetle can cause in comparatively new buildings, a true picture of its distribution throughout Britain is needed. The Ministry of Health has therefore requested Public Health authorities to keep a look-out for this type of insect damage. Property owners and householders can do much to assist this work by notifying the Forest Products Research Laboratory, Princes Risborough, Bucks, if they have any reason to suspect the presence of House Longhorn Beetles in their roofing timbers.

Photosynthesis

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It is the fundamental characteristic of the green plant that it absorbs the raw materials of air and soil and builds them into its own body and so manufactures the exceedingly numerous and varied substances necessary for its own growth. But the bodies of green plants, either immediately or ultimately, provide the food of practically all non-green plants and all animals, including Man. Apart from a few lowly organisms, such as certain groups of bacteria, all living things on this planet are dependent for their existence on the activity of green plants. Although the elements contained in the substances which make up the plant body are all derived from air and soil, in the plant they are present for the most part in compounds of higher energy content than that possessed by the simpler substances of the environment from which they are formed. To effect the synthesis of the substances of the plant body a supply of energy is therefore required; this energy is provided by sunlight. The process in which the radiant energy of the sun is absorbed is known as carbon assimilation or photosynthesis. In this process carbon dioxide from the air and water from the soil are synthesised into carbohydrates, probably sugar in the first place, a transformation requiring a considerable quantity of energy, actually about 3·75 kilogram-calories for every gram of sugar produced. This is the fundamental process by which the energy provided by the sun is absorbed and utilised by the green plant.

Only plants containing the green pigments known collectively as chlorophyll, and only those parts of such plants containing chlorophyll, are able to do this. Obviously chlorophyll is an essential factor in photosynthesis.

While one should not be too dogmatic on the matter, it would appear that this production of sugar from carbon dioxide and water is the only process in which the radiant energy of the sun is trapped, as it were, and made available for life. The sugar so produced is subsequently broken down in the plant to carbon dioxide and water by the process called respiration, and in this breaking down the energy contained in the sugar is released and utilised in the formation of the innumerable other substances which make up the plant body.

There can be no question that photosynthesis is of paramount importance in the world, and has been aptly described as the most important of all manufacturing processes. Not only is life on this planet absolutely dependent on it, but the industrial developments of the last two centuries have also been completely dependent on it. These have been brought about by the utilisation of the energy stored in coal, and to a less extent, of so-called mineral oil. It was photosynthesis in bygone ages that resulted in the production of the plants the remains of which form coal, and indirectly of the animals that probably formed the source of mineral oil. The energy obtained from coal today was provided by the sun millions of years ago. Thus all industries utilising plant and animal materials, coal or oil, are all dependent ultimately on photosynthesis.

The production of sugar by the green plant is not only the most important manufacturing process; it is also the biggest. Beginning with that of Liebig in 1840 a number of calculations of the annual amount of photosynthesis have been made, and while such estimates are necessarily only approximate, they vary much less than one would expect, ranging from about $1{\cdot}8\times10^{10}$ to 3×10^{10} tons of carbon converted by land plants from its inorganic form as carbon dioxide to organic material in a year. These correspond to the production of from 45,000 million to 75,000 million tons of sugar. These estimates, however, take no account of photosynthesis in the oceans. The seas of the world contain vast quantities of photosynthesising plants, chiefly floating plants called phytoplankton mainly made up of tiny organisms, the diatoms, which occupy a layer about 300 feet deep. While calculations of the amount of photosynthesis occurring in the oceans are much more problematic than those concerning land plants, a recent estimate by Rabinowitch that the total photosynthesis in the oceans is about seven or eight times that of the land areas seems reasonable. A conservative estimate of the annual total photosynthesis of the world would thus be over 300,000 million tons of sugar. This would mean that the annual production of sugar by plants is something like 2000 times as great as the world production of steel.

The realisation of the supreme importance of photosynthesis appears to have come gradually during the nineteenth century. The eighteenth-century pioneers of plant physiology, Priestley and Ingenhousz in England, and Senebier in Switzerland, were chiefly concerned with the hygienic attributes of the green plant in removing carbon dioxide from the air and supplying it with oxygen, but it was due to these men and to de Saussure, who a little later put knowledge of the subject on a quantitative basis, that the fundamental facts that plants absorbed carbon dioxide from the air and gave out oxygen into it, that only the green parts of plants can do this, and that light is necessary, became known. That the absorption of carbon dioxide resulted in the formation of carbohydrate was not definitely established until the researches of Sachs in the middle years of the nineteenth century, although this had been suspected for some time previously.

With the work of Sachs the overall reaction in photosynthesis was known: carbon dioxide and water in presence of chlorophyll and light produce carbohydrate and oxygen. There has been, and still is, controversy as to which carbohydrate is first formed, for photosynthesising leaves generally contain a mixture of these, but the more general view is that hexose sugars such as glucose and fructose precede the more complex disaccharide cane sugar and the polysaccharide starch.

Since the middle of the last century a constant stream of investigators have sought by one means or another to obtain information that would help to explain the mechanism of the photosynthetic process, but although much valuable knowledge has been obtained the course of the photosynthetic process is far from being known and no-one has yet succeeded in imitating the process outside the living plant.

Investigations have followed several different lines. Since green pigments are essential for photosynthesis a determination of their composition and properties might obviously be helpful in assessing the part they play. After much indecisive work by numerous workers the leaf pigments were separated by the conclusive work of Tsvett and of Willstätter and Stoll in the early years of the present century. For the separation of the pigments Tsvett introduced the chromatographic method which has more recently been elaborated by chemists into a popular analytical technique. He allowed an extract of the pigments to percolate through a column of an adsorbent such as powdered chalk, when the different pigments are adsorbed at different levels. Willstätter and Stoll used a principle due to the physicist G. G. Stokes, in which the mixed pigments after extraction from the leaf are transferred to a vessel containing two immiscible liquids, such as petroleum ether and aqueous acetone. As the relative solubilities of the various pigments are different in different solvents a separation of the pigments can be effected by this means. The work of Tsvett and Willstätter showed that higher plants contained two green pigments (*chlorophyll a* and *chlorophyll b*) and two yellow pigments or two groups of yellow pigments (*xanthophyll* and *carotene*). More recently it has been shown that other chlorophylls (*chlorophyll c* and *chlorophyll d*) may occur in some lower plants. Willstätter and Stoll further determined the composition and properties of the pigments. It must be admitted that this and later work has so far contributed little to our understanding of the mechanism of photosynthesis. Willstätter and Stoll thought that chlorophyll absorbed carbon dioxide, forming a compound with it, but more recent work has shown that this is very unlikely. What does appear is that the two chlorophylls have different absorption spectra, so that a wider range of radiation can be absorbed by the two chlorophylls than by one. The chlorophyll probably acts as a catalyst in a photochemical reaction in which the absorbed energy is transferred to reactants in the photosynthetic process, but at what stage this occurs and what the reaction may be are quite problematic.

A second mode of attacking the problems of photosynthesis has been to examine the effects of the various conditioning factors, such as temperature, light intensity and carbon dioxide concentration, on the rate of the process. Work on these lines, carried out over a period of some twenty years in Cambridge under the inspiration of the late F. F. Blackman, afforded the first real step in the analysis of the photosynthetic process. It was shown tnat under conditions of high light intensity temperature had a considerable effect on the rate of photosynthesis, and that if the carbon dioxide concentration was not too low, within certain limits of temperature a rise of 10° C. brought about an approximate doubling of the rate of photosynthesis. This relationship is characteristic of ordinary chemical reactions not dependent on light. On the other hand, if the light intensity were low, altering the temperature had practically no effect whereas the rate of photosynthesis was proportional to the light intensity. This relationship is that characteristic of photochemical reactions. Thus it was concluded that in addition to the action requiring light, photosynthesis must also involve a chemical or dark reaction. With low light intensity the rate of the whole process is controlled by the photochemical reaction; in high light intensity the rate of the whole process depends on the rate of which the dark reaction can proceed.

A third line of attack on the mechanism of photosynthesis, developed in more recent years, has involved experiments carried out with chlorophyll-containing granules (*chloroplasts*) outside the living plant.

The factory in which the sugar is manufactured is the green cell, and as every student of botany knows, the green pigment is localised in *chloroplasts* (which are small granular bodies), in which the green pigment is held in association with protein and fatty substances. Since the green pigment is an essential part of the photosynthetic system it is reasonable to suppose that the chloroplasts are the actual seat of the photosynthetic process. Various attempts to demonstrate photosynthesis in chloroplasts isolated from other cell contents have for the most part failed, and until about twelve years ago the most that could be claimed from experiments with isolated chloroplasts was that on exposure to light these might give rise to a feeble evolution of oxygen.

However, some twelve years ago it was shown by R. Hill that under certain conditions isolated chloroplasts when exposed to light could give out very definite quantities of oxygen. This occurred if the chloroplasts were in presence of a leaf extract, but it was found that the same

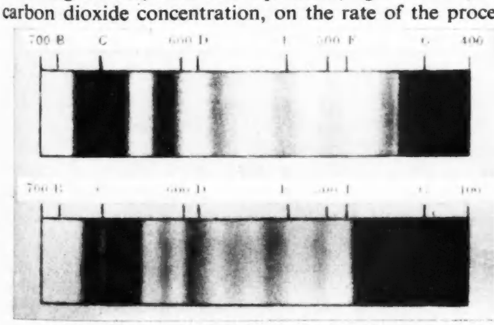


FIG. 1.—Absorption spectra of chlorophyll. (*Above*) chlorophyll a: (*below*) chlorophyll b.

FIG. 2.—(*Right*) Sachs's drawings of chloroplasts. (A): cells of a moss with chloroplasts. (B): isolated chloroplasts. *a–e* shows enclosed starch; *f*. chloroplast swollen in water; *g*, starch left after dissolving away the chloroplast; *b*, *b* chloroplasts dividing. *Right:* the alga *Spirogyra* with band-shaped spiral chloroplasts.

effect could be brought about by simpler systems than leaf extracts. Thus ferric salts and a number of organic substances including quinones, can be used in place of the leaf extract. Accompanying the evolution of oxygen is a reduction of the substance present, the ferric salt, for example, being reduced to the corresponding ferrous salt. The chloroplasts, it would thus appear, contain a mechanism which will reduce various substances in presence of light with evolution of oxygen. There is quite good evidence that this mechanism demonstrated by Hill is that which functions in photosynthesis and leads to the evolution of oxygen in that process. Thus various substances such as urethane, hydroxylamine and sodium azide, which inhibit photosynthesis, also inhibit the evolution of oxygen by isolated chloroplasts. What the substance is that is concerned with the evolution of oxygen in photosynthesis is not known. The evolution of oxygen by isolated chloroplasts is not accompanied by any absorption of carbon dioxide, so it would appear that the absorption of carbon dioxide and the evolution of oxygen are concerned in separate stages of the whole photosynthetic process. It would further appear that the evolution of oxygen is connected with the reduction process brought about by the absorption of light energy and that the first reactions in which carbon dioxide is involved are not effected through light energy. It was a popular view in the latter part of the nineteenth and in the early years of the twentieth century that light effected a breaking up of carbon dioxide to carbon monoxide and oxygen ('photolysis of carbon dioxide'). This view, which never rested on any foundation of fact, would now seem to be definitely wrong.

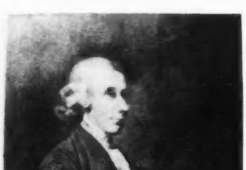
A fourth way in which information has been sought on the mechanism of photosynthesis is a search for intermediate products. Various intermediates have been suggested, but of these formaldehyde was for about 70 years the favourite, and many writers appear to have accepted the formaldehyde theory as fact.

A critical consideration of the evidence that has been adduced from time to time in favour of this view reveals that the theory rested on no sound basis, and more recent work has shown that it is untenable. Thus it has been found that when photosynthesising cells of the unicellular alga *Chlorella* are supplied with carbon dioxide and water in which the oxygen is in the form of a radioactive isotope, all the oxygen given out in photosynthesis comes from the water and none from the carbon dioxide. If formaldehyde were the first product of photosynthesis at least half the oxygen would have to be provided by the carbon dioxide.

The search for intermediate products of photosynthesis has been continued in recent years by means of experiments in which the carbon dioxide supplied to photosynthesising cells has contained radioactive carbon. By the use of such tracer carbon it would be expected that the various compounds containing the carbon during its passage into the sugar molecule could be determined. Earlier work on these lines, carried out in California just before and at the beginning of the war, was hampered by the fact that a carbon isotope with only a short radioactive life was available. During the last few years, however, an isotope with a vastly longer radioactive life has been available and the experiments now being carried out by Calvin and other investigators in America are much more promising. It has been announced that the first carbon-containing product to be recognised in this way in photosynthesis is phosphoglyceric acid, a substance which is also an intermediate when sugar breaks down in respiration. It is now known that organic phosphates play an important part in the transference of energy in plant metabolism and we should therefore not be surprised if phosphorylated compounds such as this glycerol compound are involved in the production of sugar. It is most improbable that a three-carbon compound such as glycerol arises directly from carbon-dioxide and we must suppose that there are intermediates between carbon dioxide and the glycerol stage. It is interesting that more than half a century ago the famous chemist Van't Hoff suggested that the synthesis of sugar from carbon dioxide and water might follow in part the same course, but in the reverse direction, of the breaking down of sugar in respiration. It would seem that his suggestion may have been justified, but we must wait for further results before we shall know how justified this suggestion was. Plant physiologists await with interest further results of this most promising line of research with radioactive tracers.

Although then, as a result of a vast quantity of research along a number of different lines, our knowledge of certain details of the course of photosynthesis is much surer than it was even ten or twelve years ago, we are clearly very far from understanding the mechanism of the process and so of solving the problem of how the green plant utilises solar energy. In view, however, of the great advances made in other branches of science, there is no reason to suppose that this problem will not ultimately be solved and the utilisation of solar energy made possible by methods similar to those employed in photosynthesis but without the agency of the living plant. It is not outside the realms of possibility that the chemist may also succeed in preparing in the laboratory that vast number of substances which are produced in the plant body. But that stage in the development of scientific knowledge we may feel confident is far distant, and we may rest assured that in any event the green plant will remain the principal agent for the conversion of solar energy for the maintenance of life and human activities.

TWO PIONEERS OF PHOTOSYNTHESIS RESEARCH.



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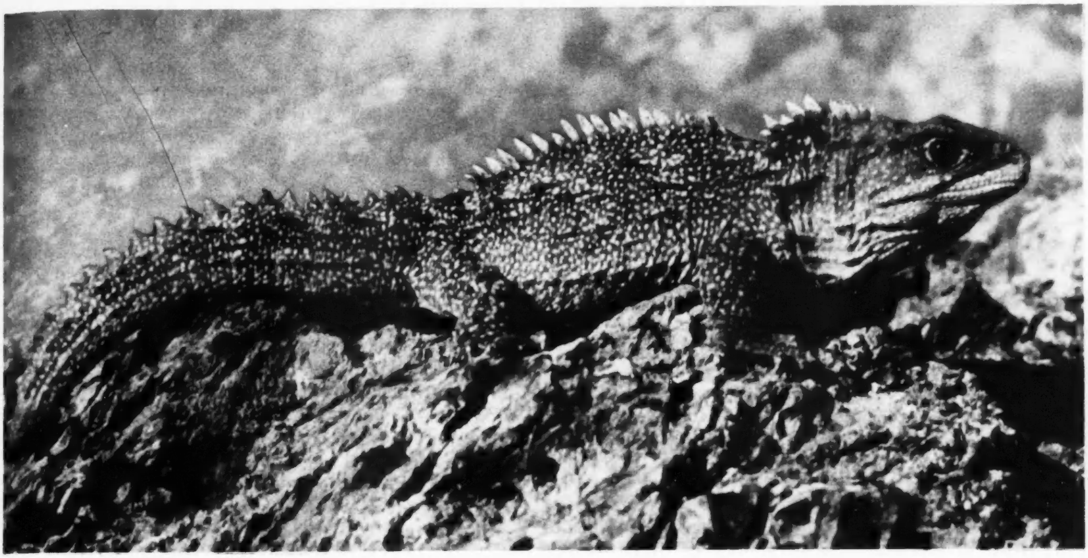

Last of an Ancient Race

R. P. HILL, B.Sc., D.I.C.

ISLANDS which long ago became separated from the main land-masses of this planet are apt to harbour animals of unusual types—animals that are in fact relics of the fauna which existed at the time of separation. Sheltered by the sea from the competition that led to the annihilation of their relatives on the mainland, these creatures have been able to survive, and sometimes even to evolve along lines of their own, as did the marsupials of Australia after the breaking of the land-link with Asia. New Zealand, which was isolated still earlier than Australia, has no indigenous mammals at all. Its relics consist of two rather primitive flightless birds—the little Kiwi and the huge (and now extinct) Moa—and one extraordinary reptile, known to zoologists as *Sphenodon punctatum*.

There is nothing very remarkable about *Sphenodon's* outward appearance. It looks like a rather heavily built lizard, and is about two feet long and bears spiny scales on the hinder part of the head and along the back, which caused the Maoris to name it 'Tuatara' (having spines). Before the arrival of Europeans in New Zealand, Tuataras were plentiful on the mainland. Now they are confined to a few small islands in Cook Strait, where they live under the strict and anxious protection of the New Zealand Government. Even so, the chances that the species will survive are not good.

The Tuatara is retiring in its habits—a fact that may have contributed to its survival thus far—the rocks contain plenty of evidence in support of the dictum that "the meek shall inherit the earth". During the day *Sphenodon* hides itself in a burrow about five feet long, narrow at the opening but widening out into a chamber at the inner end, from which it issues forth at night in search of worms, insects, frogs and other small animals on which it feeds. Although never more than one Tuatara is found in a single burrow, the creature often shares its living-quarters with a petrel. When this occurs the reptile nearly always occupies the right-hand side of the chamber while the bird lives on the left.

The uniqueness of *Sphenodon* begins to emerge when one attempts to assign it a place in the classification of animals. Despite its superficial resemblance to the true lizards, the structure of the skull and jaws is such as to exclude *Sphenodon* from the Order Squamata (to which the lizards and snakes belong). Certain other of its skeletal features are found in crocodiles (Order Crocodilia) and turtles (Order Chelonia), although it is evident that *Sphenodon* belongs to neither of these groups. Since all other living reptiles are put in one or other of these three orders, it is clear that *Sphenodon* must be the sole living representative of a fourth order. Zoologists have named this the Order Rhynchocephalia.

A classification of the reptiles must, however, go beyond the living representatives of the class; it must embrace all those reptiles now extinct whose fossilised skeletons have been dug out of the rocks. This provides a constant check on the validity of the classification and necessitates periodic revisions in the light of new facts and interpretations. The ultimate aim of such a classification is to provide a complete 'family-tree' of the group in question. It must be admitted that the reptile classification has a long way to go before it can approach this ideal: many of the branches and much of the main trunk are still imperfectly known. Unfortunately—but understandably—the biggest gaps in our knowledge occur at the most important points—at the points, that is, where the branches join the trunk. After all, the chances that a given animal will become fossilised, that its remains will be preserved intact despite movements of the earth's crust and that it will be discovered by man

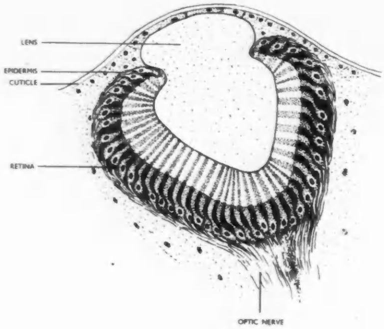

FIG. 1.—Eye of *Nereis*.

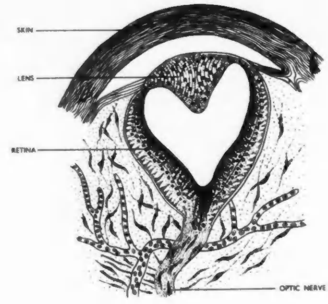

FIG. 2.—Pineal eye of *Sphenodon*.

several hundred million years later are small. Most of the fossils we find, therefore, will be those of species which existed in fairly large numbers. Great numerical strength may be taken as an indication of successful specialisation. Specialisation in turn indicates that the potentialities of the stock have been largely realised and that no further evolutionary advance of a major kind can be expected of it. Thus, as we trace the evolutionary history of a group back through rocks of increasing age, we find the group characteristics preserved intact although increasing numbers of primitive features are shown. Then, quite abruptly, the fossil record of the group peters out, leaving us to speculate about its precise ancestry. This is true of all the major reptile groups. The Squamata (the lizards and snakes), nowadays by far the largest order, appears to be the youngest. They are not found in rocks older than the Upper Jurassic, and have therefore existed for something like 150 million years. The Crocodilia and Chelonia are a good deal older than this, dating from the middle Trias —about 180 million years ago.

The fossil record of the Rhynchocephalia is extraordinary. *Sphenodon* itself is not found fossil, indeed none of its fossil relatives are found in rocks laid down less than 100 million years ago. Judging by the number of these fossils that have been found, the group was not a very large one and flourished mainly in the Triassic and Jurassic periods in whose rocks several species closely resembling *Sphenodon* are found. The group thus attained the peak of its development far earlier than any of the other existing orders of reptiles—earlier, in fact, than the Dinosaurs. The probable ancestors of these later types of Rhynchocephalia have been found in rocks of Permian age laid down well over 200 million years ago. Since the first reptiles, scarcely distinguishable from their amphibian ancestors, are found in Upper Carboniferous rocks not more than 230 million years old, any distinct group emerging in the Permian age which followed must be counted among the earliest experiments in reptile evolution. Most of these Permian forms had died out by the Triassic, although not before some of them had given rise to new groups which were the precursors not only of modern reptiles but of the birds and the mammals. The Rhynchocephalia, however, did not share the fate of their contemporaries. Retaining their identity and enjoying a modest success, they lived quietly on through the next incredible 100 million years while a succession of ever-mightier reptiles arose to dominate the land, the seas and the air. Yet when, some 60 million years ago, disaster overtook all the great reptiles and threw the world wide open to the birds and mammals, the ancestors of *Sphenodon* remained among the survivors. It is doubtful whether they could have competed as the lizards and snakes did with the vigorous new mammals, but again they were rescued from extinction by chance. And so, shielded from competition, they remain to this day—a few members of a single species restricted to one spot on the earth's surface.

Apart from being the most primitive of living reptiles, *Sphenodon* has one other claim to distinction: it possesses a pineal 'eye' which is much better developed than that of any other living vertebrate. The pineal apparatus is something of a mystery. It occurs in all vertebrates, including Man, as an outgrowth from the roof of the hinder part of the fore-brain. Usually, as in ourselves, it consists merely of a stalk of varying length (the *pineal stalk*) surmounted by a little swelling (the *pineal body*), the whole apparatus being enclosed within the skull. In some vertebrates, however, there is a hole in the roof of the skull (the *pineal foramen*) through which an additional part of the pineal apparatus projects so that it lies just under the skin on top of the head. In such instances this extra portion of the apparatus takes the form of an 'eye' which, although it may be joined to the pineal body by strands of connective tissue, has no nervous connexion with the brain. As can be seen from Fig. 2, there is no mistaking its eye-like structure. It is, however, quite unlike the normal vertebrate eye (Fig. 3): on the contrary, it resembles more closely certain types of eye found in invertebrates (Fig. 1). Although *Sphenodon's* pineal eye is so perfectly developed there can be no question that it functions as an eye. Apart from the fact that it has no nervous connexion with the brain it is completely covered with opaque skin. However, in certain other reptiles in which the pineal eye itself is less perfect it is covered by a special transparent scale. This can have no other function than to allow light to fall on the organ.

In Man the pineal apparatus lies entirely within the skull and, owing to the enormous development of the cerebral hemispheres, it appears to be embedded in the

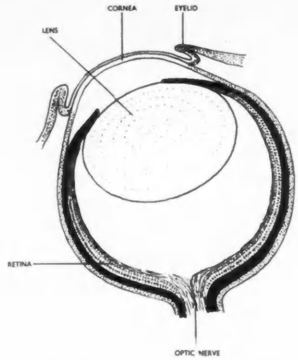

FIG. 3.—Section of typical vertebrate eye.

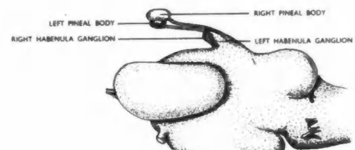

FIG. 4.—Brain of Lamprey.

very centre of the brain mass. Its position led some early anatomists to regard it as the seat of the soul. In the absence of direct evidence this view is no longer held, but the true function of the pineal remains uncertain. Because of the nature of its cells the pineal body is often listed among the body's ductless glands, but no one has succeeded in isolating the hormone it is supposed to secrete or in showing how, where and when this hormone exerts an effect. Some years ago it was suggested that the pineal exerts a control over the rate of development of the secondary sexual characters, sexual precocity having been observed in experimental animals from which the pineal had been removed. Further experiments failed to confirm this and the functions, if any, of the human pineal are as big a mystery today as ever they were.

If, however, we travel to the other end of the scale of vertebrate complexity, we can find an animal in which the pineal apparatus is still to some extent functional. This animal is that rather primitive, jaw-less, limb-less, fish-like creature—the Lamprey. If we accept the Lamprey as primitive, then we may regard its pineal apparatus as illustrating the primitive vertebrate condition. And in the Lamprey the pineal apparatus is double (Fig. 4). In the hinder part of the roof of the fore-brain there are two aggregations of nervous material known as the ganglia habenulae. From each ganglion arises a stalk on the end of which is a degenerate eye-like body. The right ganglion and stalk are larger than the left, while the right 'eye' is not only larger and less degenerate than the left one, but lies above it in a pineal foramen. A little patch of skin above this foramen is transparent and unpigmented, and experiments with blinded Lampreys have shown that this right half of the pineal apparatus is sensitive to light.

The condition in the Lamprey suggests a pair of simple median eyes in some ancestor, of which first the left one became vestigial and then the right followed suit. A continuation of this process of degeneration might well lead to the state of affairs found in most vertebrates wherein one half of the double pineal apparatus has disappeared entirely while the other half is greatly reduced. On this hypothesis it would be the right half of the apparatus that persisted: in fact it is the left half that has survived. The truth of this unlikely statement becomes evident when the condition in the lizards, monitors and *Sphenodon* is considered. Here the usual pineal body and stalk are present, although the former shows little evidence of eye-like structure. But in addition, lying above the pineal body in a pineal foramen, is the well-developed pineal eye. There can be little doubt, in spite of the absence of a stalk, that this is the homologue of the better-developed right pineal eye of the Lamprey—which means that the normal pineal body and stalk must correspond with the left half of the Lamprey's apparatus. The mystery of the pineal thus becomes deeper and more involved.

It is evident from the condition of the pineal apparatus in *Sphenodon* and other modern reptiles that some common ancestor of theirs had a functional pineal eye. How far back in time that ancestor lay is well-nigh impossible to determine; yet the fairly widespread occurrence of transparent pineal scales and the fact that *Sphenodon*, the most primitive of all living reptiles, has the best developed pineal eye suggests that this ancestor may have been an early reptile. Unless one accepts the unlikely hypothesis that in some early reptiles the degenerate pineal eye enjoyed a second lease of functional life, this implies that the amphibians from which the reptiles arose and the fish that gave rise to the amphibians must all have had functional pineal eyes. Indeed, the occurrence of a pineal foramen in most of these early skulls does strongly suggest that a pineal eye was present, but we cannot even hope for any evidence that might show to what extent, if any, it was functional.

The story so far, although highly speculative, is at least plausible. But we have still to explain why it is that the left half of the pineal apparatus, which was the first to begin degenerating, has persisted right through to Man while the right half, which may have retained some part of its original function as far as the reptile stage in vertebrate evolution, has disappeared. Such a state of affairs might be explained by suggesting that the left half, during the course of its early degeneration, acquired a new and different function and was thus able to persist in modified form, while the right half, degenerating at a later date, acquired no new function and so disappeared entirely. But an explanation on these lines leads us straight back to the description of the pineal body as a ductless gland and to a reiteration of the admission that we have so far failed either to identify its secretion or to establish its function. In short, if the pineal body is not a ductless gland and if it is not the seat of the soul, it has no business to be there at all! Yet there it is. . . .

SERUM AND VACCINE PRODUCTION

(*Left*)—Filtering culture medium using a pressure tank.

(*Right*) – Filling ampoules with serum.

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The Evans Biological Institute

CLIFFORD TROKE

This account of The Evans Biological Institute, an old-established group of laboratories now nearing their fiftieth year, throws an interesting light on the progress of the pharmaceutical industry during the present century.

THE group of laboratories now known as The Evans Biological Institute originated nearly fifty years ago out of researches undertaken by Liverpool University. Much of this work, begun at the turn of the century, was of classic quality, and advanced considerably knowledge of vaccines, of tropical medicine, and of the new compounds which ushered in the age of chemotherapy. It grew so rapidly that the cramped quarters in the city had no space for it, and in August 1902 it was decided to set up at Runcorn, a few miles down the Ship Canal, what was termed a 'farm station'. Here the horses needed for the making of sera could be kept under proper control.

Those who planned the new enterprise had good reason to think that it would largely pay for itself, for immunising agents had an expanding market; but academic genius is one thing, financial acumen another, and within ten years it was clear that the prestige of the laboratory's products was not being reflected in the balance sheet. Today a project of equal standing, vitally related to health, would almost certainly obtain some form of state subsidy, but in those days science in general sank or swam on its own. If the old Liverpool firm of Evans had not come to the rescue the Runcorn institute would have foundered. As it was, both sides had misgivings. The shareholders thought research highfaluting; the professors thought commerce crude. But as so often has happened in British institutions, apparent incompatibles invigorated one the other. Twenty-five years later, in 1937, when both the farm station and the chemical laboratories now adjoining it had so grown that drastic rebuilding was called for, it was the Chancellor of Liverpool University, Lord Derby, who performed the opening ceremony. Though financial separation was complete, the old academic ties remained.

It has been remarked by an elderly and respected member of the E.B.I. staff that life there is one long market-day. The parallel is understandable. Two hundred horses, together with sheep, an occasional cow, a pig or so, and a large population of lesser livestock—fowls, rabbits, guinea-pigs—does not make for cloistral calm; but the main work of the institute, to prepare from living tissue substances to check life's numerous ills, covers not only man, but most of his domesticated creatures, and the scientist disturbed at his thesis by the gobbling of a turkey can reflect that it is not unworthy a task for science to protect the Christmas dinner.

Sera and Vaccines

The two main techniques of the veterinary side are the production of sera and vaccines. The serum is a means of supplying directly the antibodies which combat bacteria; whereas the vaccine stimulates their production by the threatened animal itself. To obtain a serum against lamb dysentery, for example, a horse is injected with dysentery vaccine every few days for about three months. The effect of this is to produce in the blood a considerable concentration of antibodies. Mice injected with dysentery toxin in amounts known to be fatal are now given varying quantities of blood serum from the horse. Too small a dose of preventive serum means death, but those who have a large enough dose recover. If the strength of the serum, measured in this way, is sufficient, then about 1½ gallons of blood are drawn painlessly from the horse's jugular vein, and the serum from it, after passing standard tests, and with a small quantity of preservative added, is bottled for use by the veterinary surgeon.

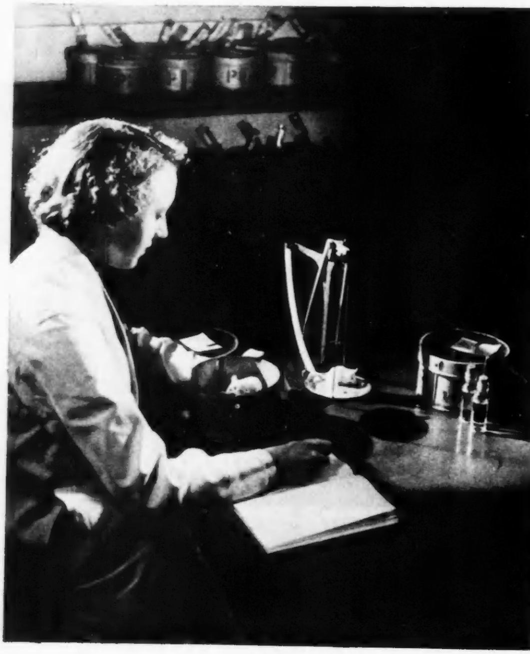
Methods of serum preparation are fairly uniform, but those of vaccines vary. Sometimes a germ is bred till a strain is obtained of optimum strength—not strong enough to kill, yet strong enough to produce a good defensive response. Or the bacterium may be killed before injection, so that though it cannot multiply, it will, by its toxic presence, set the processes of antibody-production in motion. Another technique is the extraction of its toxin from a bacterium, and the administration of the poison in small doses as stimulant of the defences. But in certain cases—louping ill of sheep, for instance—the vaccine can be prepared only from the solid tissues of an infected animal. Louping ill, a type of paralysis, is caused by an ultra-microscopic virus carried by a tick. To provide protection against it a healthy sheep is fatally infected, and a vaccine prepared by grinding up its nervous tissues—for it is the brain and spinal cord which the virus attacks. The vaccine is injected just below the sheep's skin. This must be done about fourteen days before the ticks begin to be active, that is, early in March.

The production of veterinary substances at E.B.I. is on a very large scale; some thirty animal ailments, including such sheep diseases as braxy, blackleg, and strike are provided against. There are, for example, injections against contagious abortion in cattle, canine distemper, and as regards the pig, swine fever and erysipelas. But from its earliest days the institute has prepared biological antidotes to human diseases.

In the files are the old leaflets concerning the use of the first anti-tetanus and anti-plague preparations, some of the phraseology as remote as the spidery black print.

On the outbreak of war in 1914 German-held patents were seized, among them those covering the treatment of syphilis by Ehrlich's 606, salvarsan. This was thereupon manufactured at Runcorn, and a pamphlet was issued on its use, a clear but rather scholarly exposition, this, with *therapia magna* for massive dose, and the maxim *corpora non agunt nisi fixata*—"no creature is killed unless fixed" —quoted as "the governing principle of chemiotherapeutics" (*sic*).

LABORATORY CONTROL



(*Left*)—Weighing mice prior to biological assay work. (*Right*)—Floculation test for Diphtheria Antitoxin.

(*Left*)—A viscosity test on hyaluronidase. (*Right*)—Measuring a skin reaction in tuberculin testing.

Liver E

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Liver Extracts

In 1926 a discovery was made which led E.B.I. to embark upon a long train of research which, in fact, still continues. This discovery was the liver treatment for pernicious anaemia introduced by two Americans, Minot and Murphy. Pernicious anaemia had till then been an almost uniformly fatal disease; now it was established that the eating of liver could check it. So great, however, was the consumption called for, and so unpalatable the remedy, that methods of reducing bulk-intake were quickly sought. The first liquid oral extract of liver in Britain was produced at Runcorn in 1928, and two years later a liver preparation for injection was issued; while in 1943 came an interesting development, the proteolysis of liver. The need of the pernicious anaemia patient for the curative principle of liver to be extracted in the smallest possible bulk had so far been met by chemical extraction, in which substances such as phenol were used. The Runcorn research team decided to break down the liver by more digestive agents and succeeded after some difficulty in using the enzyme papain for this purpose.

Some three years ago the 'red vitamin' B_{12} (an anti-pernicious anaemia factor) was isolated from liver. It was later found to be produced by *Streptomyces griseus*—the same organism, half-way between bacteria and fungus, from which the antibiotic streptomycin is prepared. Research at the E.B.I. showed that organisms in the digestive tract of the horse were also manufacturing B_{12}; and it was soon established that the bacterial flora of the human digestive system are in fact the main source of the vitamin in our diet. The question of what prevents its absorption in cases of pernicious anaemia has at least been partly answered by work at the institute. The B_{12}, though manufactured by one group of bacteria, is consumed or destroyed by others. But a substance has been isolated from the intestine which protects B_{12} by combining with it and preventing bacteria from destroying it. This isolation is an extremely delicate job. The sterilisation of the substance, for example, had to be done by high-speed centrifuge, since the least heat destroyed it. Absence of the protective factor (bound up, apparently, with lack of hydrochloric acid) is the start of pernicious anaemia.

Research into these problems continues. At the same time, experience gained in handling large quantities of animal tissue has been utilised in preparing three substances, all of considerable medical importance, yet presenting great difficulties in manufacture. These are heparin, cytochrome *c*, and hyaluronidase.

Heparin

In the early days of our century, hirudin, extracted from leeches, was used as a preventive of blood clotting, but it was too poisonous for success against thrombosis; and germanin, one of Ehrlich's drugs, though it achieved some reputation as hirudin substitute, had similar drawbacks. But in 1916 came unexpected progress. One day Howell, the great American authority on blood coagulation, gave to one of his helpers, a young student named Maclean, the job of extracting blood coagulator from brain tissue. In the coarse of the job Maclean (who was only in his second year at Johns Hopkins Hospital, Baltimore) did a most distinguished piece of work and produced, in addition to the substance he was after, another substance, a phosphatide, which in fact *prevented* coagulation. The anti-coagulant was also found in heart tissue, muscle, lymph nodes, and again, in fair quantity, in the liver, from which last fact it was named heparin. Physiologists have now discovered exactly where the heparin comes from—it is formed in certain cells widely distributed in the body—the 'mast cells', which are found in connective tissues, always near the arterioles. These cells, which stain a beautiful purple with the dye toluidine blue, are sometimes called heparinocytes because the heparin arises from granules contained in them.

Heparin is now being manufactured at Runcorn, the method being to extract it from minced lung tissue. It is a very long business with ten or a dozen major stages; and a considerable number of tests on animals is necessary to ensure high purity. But the purified heparin is already finding many uses in medicine. One use is particularly neat and simple. Small phials for blood samples have been made containing just a trace of heparin. They are quite inexpensive, but the physician equipped with them can be certain that his blood samples will not clot.

Heparin is a polysaccharide, that is a complex sugar. It also carries—this is a particularly interesting point—an exceptionally strong electric charge. The function of this heavy charge on the molecule is somewhat mysterious, but it seems that the heparin changes the charge of thrombokinase, or it may be of the prothrombin—these are the clotting substances of the blood—and thus renders them inactive. A most subtle problem here awaits the biochemist. Perhaps the most authoritative account of heparin so far is the work of Jorpes, a Swedish research worker.

Cytochrome

Usually when we speak of breathing it is the *supply* of oxygen we are thinking of. This depends on the state of the air, the efficiency of our lungs, and the oxygen-carrying power of the red cells of the blood. This power to carry oxygen in turn depends on their pigment haemoglobin which combines loosely with oxygen, conveys it to every cell in the body, liberates it, and loads up with carbon dioxide for the return journey. The cells (say the text-books) use the oxygen to burn the food they contain and this gives the energy needed for the various bodily processes. In fact, what goes on in the cell is a series of reactions vastly more complex than burning. The main outline of the process is known, however, and it depends on a group of substances which have been named the cytochromes.

The story of the discovery of the cytochromes begins as far back as 1918, when the great biochemist Otto Warburg, working in Germany, noted that carbon monoxide forms complex compounds with iron which break up under the action of light. In an ingenious experiment he showed that if living cells were taken and poisoned by carbon monoxide they recovered their power to use oxygen, that is to breathe again, when strong light fell upon them. Warburg concluded from this that the substance in the cells which governed their respiration was a complex substance containing iron.

Proof of this came from H. J. Keilin, a physiologist, working in a research institute at Cambridge. He performed a remarkable experiment which remains a classic in its field. By very delicate manipulation he managed to observe spectroscopically light passing through the muscles of an insect's wing. Enormous energy is required to maintain an insect's wing-beat. Keilin thought that the oxidation processes producing this were certain to be visible as spectroscopic changes. And he was right. When the insect was at rest four clear absorption bands were present; and as soon as the furious motion of flight began they abruptly shifted their position in the spectrum showing that a new substance had been formed.

By close observation Keilin found that the bands changed position according to the contraction and relaxation of the wing muscles, in other words, according to the oxidation and de-oxidation which gave the energy. Keilin next discovered that the substance involved was an iron-containing pigment, which he named cytochrome. He showed that it was widely distributed throughout the animal world, including the bacteria—that it was present, in fact, wherever oxygen respiration was practised, and that the rate of respiration in any cell was proportional to the amount of cytochrome in it.

It is now known that there are three cytochromes, *a*, *b* and *c*—with at least two sub-divisions of both *a* and *b*, but cytochrome *c*, being soluble, is easiest to extract. It is a blood pigment protein with a molecular weight of about 13,000. With its fellows it forms a subtle chemical system which interacts with the cell contents, and with oxygen, to give a continuous rhythm of oxidation and reduction.

The first medical use of cytochrome *c* was at the University of Virginia hospital. It was given intravenously to a number of elderly patients who were suffering from various states of anoxia—lack of oxygen in the body cells. Other results now confirm that first test. Failure of memory or power of concentration is counteracted; the electroencephalograph (the instrument for recording electric brain waves) shows some degree of normalisation; visual performance is markedly improved. In high-altitude pilots the drug may be able to reduce significantly those dangerous symptoms of de-oxygenation—the vague thought and illusory sense of well-being—experienced in thin air.

For some little time now E.B.I. has been producing cytochrome *c* from ox heart. Quite a few patients whose symptoms were largely those of age are being treated with it—the dose is 50 milligrams a day for 14 days. Most of them improve in general mental grasp, their arterial condition is bettered, some walk farther without pain. From certain evidence as yet unpublished it seems possible that by repeating the 14-day course at six-monthly intervals the improvement can be maintained.

Hyaluronidase

One of the most interesting substances manufactured at E.B.I. is hyaluronidase. This enzyme, first known as the 'diffusing factor', was discovered in 1928 by the French medical biologist Duran-Reynals, who, after a preliminary announcement in Paris, published a fuller account of his findings in the *Journal of Experimental Medicine* the following year. He described experiments on rabbits showing how the skin signs of vaccinial infection (that is, lesions caused by organisms of the small-pox type) became notably greater when an aqueous extract of rabbit, guinea-pig, or rat testicle was injected. It was ten years before the 'spreading mechanism' producing the increased permeability of the tissues was explained. Then it was shown to be due to a destruction of hyaluronic acid, a substance which gives cohesion to the cementing fluids of connective tissue, and hence acts as a barrier to diffusion. Experiments in America showed that hyaluronic acid is present in large amounts in the vitreous humour of the eye, and that a sulphuric ester of the acid, present in the cornea, is apparently continuously broken down by an enzyme to give the transparency on which vision depends. The enzyme responsible for the destruction of hyaluronic acid, hyaluronidase, is the diffusion factor of Duran-Reynals. Certain bacteria, among them the haemolytic streptococci, secrete hyaluronidase in their cell walls, where its action promotes their spread.

Hyaluronic acid, a muco polysaccharide of high molecular weight, is apparently depolymerised by the enzyme. The loss of turbidity in a standard solution is test of the presence and activity of the hyaluronidase. The main reason for the presence of hyaluronidase in the mammalian testis is presumably that it aids the spermatozoa to penetrate the protective follicle cells and so to reach the ovum. Absence of the enzyme is thus a possible cause of sterility. It is also possible that by adding it to contraceptive substances, their efficiency will be greatly increased.

The chief evidence that the enzyme promotes fertility is a series of experiments in which a semen so weak that it had failed completely to produce fertilisation of rabbits, became 80% successful when a minute quantity of hyaluronidase was added to it. But though in human sterility, too, occasional encouraging results have also been recorded, the cases are few and inconclusive. The medical uses of hyaluronidase, however, go far beyond this. It has extraordinary diffusive powers. Even Indian ink diffuses rapidly into animal tissue when a trace of hyaluronidase is added. Conceivably the enzyme will become a standard addition to all difficult injection substances. It is manufactured at E.B.I. from animal testes, by a lengthy extraction process culminating in freeze-drying.

This account, necessarily brief and incomplete, of the growth and work of a biological institute now approaching its fiftieth year, is a useful illustration of the time-scale of recent researches. The first trickle of results in serology and chemotherapy grows to a flood, as the ills of animals no less than humans are catered for; then the bacteria, at first enemies, become allies—witness the extraction of Vitamin B_{12} from streptomyces; finally research seeks by increasingly delicate techniques to obtain from living tissue therapeutic molecules too complex for chemical synthesis.

Looking back it seems hardly possible that the Runcorn laboratories have been at work less than two generations. But then it is only sixty years ago that the Institut Pasteur was founded.

The photographs illustrating this article were taken by Walter Nurnberg.

Allergy and the Antihistamines

R. W. RICHARDS, B.Pharm., Ph.C.

How many readers of this article suffer from hay fever? Those of you who do, and there must be a considerable number, will no doubt be well acquainted by this time with the value and remarkable effectiveness of the antihistamine drugs. Perhaps there may be a few readers who are unable to eat certain foods because of undesirable consequences in the nature of skin rashes and gastric disturbances. If so, they too can count themselves, along with the hay fever martyrs, among the thousands of unfortunates who every year fall victims to allergy in its many forms.

The discovery and subsequent development of therapeutic agents specific for the treatment of such a widespread nuisance as allergy can surely be regarded as a major achievement, and there is little doubt that with the series of drugs known as *antihistamines* we have reached another milestone in the past twenty years of notable medical progress.

The story of the antihistamines is, therefore, bound up very closely with the phenomenon of allergy and this complaint, like many others, has a very long history.

The first recorded account goes back to 1811, when Robert Bree, in an account dealing with asthma, wrote: "Hair powder has been observed in many instances to bring on first sneezing, then by association of the muscles more powers are put into action to expel the irritating matter which may have touched some points of the trachea not covered by mucus."

J. Macculloch, writing in 1828, expressed the opinion that hay fever was produced by hot-houses and greenhouses, while in 1873 a Lancashire doctor, C. H. Blackley, claimed that hay fever was due to the pollen of grasses.

Magendie in 1839 noted that dogs repeatedly injected with egg albumen often died suddenly, and in 1894 Flexner reported that animals which withstood one dose of the serum of dogs' blood would succumb to a further dose later. These recorded observations during the nineteenth century, although the investigators themselves did not realise it at the time, were ultimately to become the foundations on which the present-day concept of allergy is based.

Before this, however, conditions of hypersensitiveness to various agents had been known from very early times.

Lucretius may have been prompted to coin his famous and very often misquoted phrase *Quod aliis cibus est aliis fuat acre venenum*—what is food for some may be fierce poison for others—by this very fact. Galen (A.D. 130–200) was aware of such a condition as allergy to goat's milk. All the same, it was not until 1902 that a title was first given to the condition by the Austrian doctor Clemens von Pirquet, who called it *allergy*. Of Greek derivation, this word means, literally, "the changed ability of the body to react".

Richet's Pioneer Work

A state of affairs known as *anaphylaxis* really gave a clue as to the underlying cause of allergic manifestations, the French scientist Charles Richet being responsible for the fundamental work. Richet had interested himself in the nature of the stings of jelly fish while on a cruise, but being unable to pursue his experiments at the time, he resumed his investigations later, using instead of the poison of jelly fish that of the sea anemone.

He was puzzled when he injected the poison into dogs, because he expected that they would show some sort of reaction to the injection, but they did not.

Anaphylaxis

Imagine his surprise when on a second injection of the same material the dogs died. Richet concluded that the first dose of the anemone poison had in some way removed a natural protection which, he presumed, had hitherto existed in the dogs and that the second injection caused their death. To describe this curious phenomenon, he introduced the term *anaphylaxis*. Richet, however, was not entirely correct in his interpretation of the results of his experiments. Anaphylaxis is now known to be caused by the reaction in the body between what are known as 'antigens' and neutralising substances called 'antibodies'. Protein materials (such as Richet's sea-anemone poison), bacterial toxins, viruses and even harmless substances like egg albumen and pollen, when introduced into the blood stream, induce the formation of substances which are the antibodies. These are the body's natural defences against invasion. Antibodies are specific for particular *antigens*—this term is given to the invading substances, which persist in the blood for some little time after infection. However, in a week or so they find their way into the tissue cells of the body and there they remain indefinitely, innocuous in themselves but representing all the time a potential source of upset. For as soon as the same antigen—and it must be the same antigen—in a fairly large dose re-enters the blood stream, it inevitably reaches the cells where the antibodies are, causing an alarming reaction. This is *Richet's anaphylaxis*.

Anaphylaxis is similar in character to the clinical condition known as *immunity*.

Immunity is the result of the deliberate stimulation of antibody production as a protection against disease, and the toxins of an invading organism are consequently neutralised when they are elaborated within the body. *It will be realised, therefore, that anaphylaxis and immunity are different stages of the same reaction.* It is when the antigen is introduced into the body in fairly large amounts that anaphylaxis occurs.

The guinea pig is particularly susceptible to anaphylaxis and in this animal it is rapidly fatal, death being due to suffocation caused by constriction of the bronchioles. The rabbit, too, dies, but here the cause of death is not suffocation but heart failure, brought about by the inability of that organ to force blood through the pulmonary arteries, which like the bronchioles of the guinea pig become restricted.

True anaphylaxis is rare in man and, for obvious reasons, it cannot be experimentally induced, but although it is not very often fatal, it is extremely unpleasant. The symptoms seem to vary. An intense itching may be the first sign, swellings of the face, particularly of the eyes and lips, may be another. On the other hand, a severe drop in blood pressure may be the main clinical feature. One of the most remarkable things about anaphylaxis is the fact that its effects vary considerably from animal to animal, a phenomenon rarely experienced with any other clinical condition.

In 1910, a few years after Richet had given medical science the word 'anaphylaxis', Sir Henry Dale and his collaborator, Laidlaw, were investigating the constituents of ergot, the fungus which attacks rye and other cereals. One such constituent they discovered was *histamine*, a compound which had been described some two or three years earlier, by Windhaus and Vogt, although its physiological action was then unknown. In the course of their work they injected this substance into guinea pigs and were surprised to observe that the unfortunate creatures died, their death being preceded by symptoms of anaphylactic shock. Not only this, but when histamine was injected into other animals, the same results were produced.

After this there was little doubt that histamine was the predominating cause of anaphylactic manifestations, but the more difficult problem of ascertaining the manner of its liberation still remained to be solved, and even today this is by no means clear. It is often called a 'trigger' mechanism because the antigen/antibody reaction initiates the sudden release of histamine.

Similarity or Allergy and Anaphylaxis

Anaphylaxis and allergy are basically very similar. They are both the result of the same kind of physiological reaction, although anaphylaxis is the more acute. That there was a connexion between anaphylaxis and hay fever was suggested in 1906 by Wolff-Eisner, while in 1910, Meltzer and Karl Kroessler suggested that asthma was an anaphylactic phenomenon. An immense amount of work has been devoted in the past fifty years to the study of allergy, and many volumes have been written on the subject, but the main problem of why some people become allergic to a particular agent, and others do not, still awaits solution.

Allergy is notorious for the many different forms in which it afflicts its victims. The commonest are asthma, hay fever, migraine, urticaria (nettle rash), and a more severe form, called angioneurotic oedema, which as its name implies is characterised by swellings, coming on in some cases with startling suddenness. Some disorders of the eye and nose are also of allergic origin.

A bewildering number of substances can give rise to allergy. Pollen, foods, many drugs—even penicillin, can cause allergy, as can contact with animals (cats, rabbits, etc.), cosmetics, feathers, and a host of others too numerous to mention. Exposure to heat or cold will give rise to so-called physical allergy, showing that histamine can be released in certain instances in the absence of the antigen/antibody reaction. Small wonder that allergy in various degrees of severity is such a common disorder today, and what is more, its incidence appears to be on the increase.

At this juncture it is perhaps worth saying a little more about histamine. This is a unique substance, which is present in the body tissues, particularly the intestines, in an inert form and yet, yet so far as can be ascertained it has no essential function. If a drop of a dilute solution of histamine is scratched into the skin, a red weal is raised in about twenty minutes, characterised by a raised white bleb in the centre of the inflammation. In the normal body processes histamine is produced from the amino-acid *histidine* and destroyed by the enzyme *histaminase*. At one time it was thought that the administration of histaminase might prove of value in the treatment of allergy, but unfortunately the results were disappointing, and so its use for this purpose was abandoned.

Rather oddly, the rat and the mouse exhibit a remarkable resistance to histamine, injections of upwards of 500 mgm. per kilo of body weight being required to produce any effect as compared with the 0·5 mgm. per kilo in the guinea pig. This is reflected in the complete absence of effect of the antihistamine drugs in these animals; they tend, in fact, to supplement the toxic effects of histamine.

Even with the advent of the antihistamines, the most effective treatment of allergy is to track down the cause of the trouble, and to remove the sufferer from its influence. This commonly involves skin tests carried out by scratching into the arm drops of extracts of various likely antigens or agents causing allergy. Since an antibody reacts with its own particular allergen, releasing histamine, a red wheal will indicate the allergen which is responsible for the allergy. A process called desensitisation usually follows, entailing the gradual neutralisation of antibodies in the patient's cells by injecting minute doses of antigen. By this means the patient can often be relieved of his or her allergy.

In the drug treatment of allergy, ephedrine and adrenalin have been the main standbys, although these can only relieve, and not prevent, attacks. All the same, these drugs are still very valuable, in spite of the antihistamines.

Then, in 1937, the attention of Bovet of the Pasteur Institute of Paris was drawn to antihistaminic substances, whilst he was working on compounds antagonistic to adrenalin. He found that if he altered slightly the structure of a particular compound, which he was investigating, it became instead antagonistic to histamine. This led him to work on substances specifically antagonistic to histamine, but the compounds he produced, although possessing the desired characteristics, could not be used for the treatment of human beings, because they were too toxic.

Advent of Antihistamines

The credit for the first antihistamine which was clinically usable for the treatment of human allergy must go to Dr. Halpern of the Rhône Poulenc organisation in France, who in 1942 produced the drug known as 'Antergan'. Little news of this discovery became available until after the liberation of France.

Two years after Antergan came another and more potent anti-histamine, again the result of further research by Bovet. This was baptised 'Neoantergan' on account of its close structural relationship to Antergan. It was at about this time that news of these French discoveries began to spread, starting what eventually became a race among the various

pharmaceutical manufacturing concerns to find more potent and less toxic antihistamines. Literally hundreds of compounds were synthesised, tested and in most cases thrown away. First on the scene in the United States were *Pyribenzamine*, evolved by the American subsidiary of the Swiss Ciba organisation, and *Benadryl*, a product of Parke, Davis & Co. Benadryl, incidentally, was the first antihistamine to be introduced into Britain; it made its appearance in 1946.

Meanwhile, the Swiss chemists were not to be left behind, and from Ciba in Basle came *Antistin*, perhaps one of the safest antihistamines yet to be discovered. Other compounds were synthesised, and thus a veritable spate of these drugs came on the market. At least eighteen antihistamines were available in the U.S.A. at the beginning of 1950 although, perhaps rather fortuitously, only seven had found their way to this country.

From this it will be gathered that antihistamine research in this country was singularly unfruitful. Indeed, only one British firm can claim the discovery of a new antihistamine and even then this was due to the work of its American associate. Nevertheless, whatever British research workers may or may not have done in the antihistamine field, they have more than made up for it in other spheres of development.

Turning to the antihistamines themselves, ever since they were first discovered, the most perplexing problem which has faced the pharmacologist is the manner by which they achieve their effect. Various theories have been put forward, but most of them have been rejected for one reason or another. For example, the antihistamines do not combine with histamine to render it inert. Nor do they destroy it. There is no evidence to show that they increase the action of the histaminase either, and furthermore, they do not appear to suppress the formation of histamine. Hence, at the present time the conclusion drawn regarding their mode of action is that they block the effect of histamine by combining in the tissues in some manner with the same receptors as histamine.

It might be supposed, therefore, that for the antihistamines to replace histamine in a chemical combination they would bear some resemblance in structure to that of histamine itself. But a glance at the formulae of some of the more common members of the series shows that there is but little similarity. Many of these drugs are derivatives of ethylene diamine, $H_2N—CH_2—CH_2—NH_2$, with the hydrogen atoms attached to the nitrogen atoms replaced by other radicles. It is not clear what chemical configuration confers antihistamine activity, for even slight modifications in the molecules of the antihistamines will reduce their activity quite considerably. It is interesting to note that quite a few substances possess an antagonism towards histamine, although it is only in those which have been specifically developed for the purpose that it appears to any marked extent.

Since the antihistamines have evolved out of the research undertaken by private firms it is not unnatural that they should be commonly known by proprietary names, these being far more popular (and usually simpler) than their scientific names.

Various claims as to the efficacy of their respective products are made by the different manufacturers, but in view of the fact that the effects of the antihistamines vary from individual to individual it is not easy to assess accurately the value of any particular product.

It should be noted, however, that the antihistamines cannot alleviate a sudden attack of allergy because, once histamine has begun to exert an effect, antihistamines are powerless to prevent this. What they will do is to prevent the symptoms arising from further releases of histamine and since the original reaction will subside naturally it is not long before the condition is controlled.

In clinical use the antihistamines have proved of value for the treatment of a large number of disorders, most but not all, associated with allergy. During the season of the year between May and August considerable quantities are used for the treatment of Hay Fever, and for this troublesome complaint they are undoubtedly without equal. The pink capsules of Benadryl, the green tablets of Anthisan (Neoantergan) and the dropper bottles of Antistin-Privine (an antihistamine plus a decongestant) are a familiar sight in many medicine cupboards. The extremely irritating skin rashes (urticarias), which are a common feature of many other forms of allergy, soon succumb to antihistamine treatment. But in asthma the drugs have, oddly enough, proved most disappointing, in spite of the allergic nature of this disorder. Perhaps it is because the histamine is released in such intimate contact with those receptors with which it ultimately combines (in this case in the bronchioles) that the antihistamines are unable to get to this point in a sufficient concentration to prevent it acting. This also probably accounts for the other anomaly on the part of the antihistamines and that is in connexion with the secretion of gastric juice. Histamine is a very powerful stimulant of gastric secretion but the antihistamines do not appear to diminish this in the least.

Besides their antihistamine action these drugs are quite potent local anaesthetics but drowsiness, dizziness or vomiting in certain persons are less pleasant effects associated with their use.

For some time after they had been introduced into medicine, the general public and the lay press did not pay much attention to the antihistamines, although naturally their arrival had aroused considerable interest and speculation in medical circles. Nevertheless, the manner in which the antihistamines really did hit the headlines was not directly in connexion with the treatment of allergy, but rather in the treatment of the common cold. In 1947, an American naval doctor named Brewster treated himself for an allergy with Benadryl, when he noticed that his cold rapidly got better. Believing this due to some action on the part of the antihistamine, he selected several persons suffering from the common cold and dosed them with Benadryl, to see what effect this would have. Their snuffles and sneezes soon disappeared, and consequently Brewster then went ahead with large-scale tests, again with the same good results. Other antihistamines were tried, but it soon became evident, that in spite of the favourable reports which appeared, there were many doctors who could obtain little or no remission of the symptoms of the common cold. (Indeed, it was debatable whether those individuals obtaining relief were actually suffering from colds: most likely they were not colds at all, but allergic conditions).

Commercial organisations in the United States were quick to seize on the idea as a good selling point for antihistamines, and in the early part of 1950 colossal quantities were being manufactured and sold.

No great publicity was accorded to the antihistamine treatment of the common cold in this country. Ironically upon this caution came news of two clinical trials which had been carried out to assess the value of the antihistamines in the common cold. One series was carried out by Ciba Laboratories Limited, using their own product (called Antistin), and the other by the Medical Research Council, which used various different antihistamines. Both suggested that antihistamines had little effect on the treatment of the common cold.

But it is not only for the treatment of the common cold that the antihistamines have attracted attention. They have been found to be a very potent weapon against sea sickness and air sickness, a condition which has always puzzled scientists.

In 1947 two American doctors, Gay and Carliner, of the Johns Hopkins Hospital in the United States of America, were investigating the properties of the new antihistamine *Dramamine* (a combination of diphenhydramine and chlortheophylline), which had been sent by the manufacturers to their hospital for testing. By chance, they gave it to a pregnant woman suffering with urticaria, who had all her life been troubled by car sickness. Apart from the effect on her allergy, the drug enabled her to travel without discomfort. This was definitely no psychological effect. After further successful trials, large-scale tests were started, and because of the importance of preventing sea sickness among soldiers on troop carriers, facilities were granted for trials on a United States troopship. Dramamine reduced the incidence of sea sickness in an amazing fashion, and this triggered off a great deal of investigation of other antihistamines for the treatment of sea sickness.

At the present time it is generally considered that they show considerable promise and subsequent work will no doubt reveal their merit in this connexion.

Finally, it is relevant to mention still another useful property of the antihistamines, again not directly connected with allergy. The very distressing morning sickness of pregnancy responds quite well to administration of these drugs and this is presumably due to neutralisation of histamine, which has been shown to be present in abnormal amounts in the blood of pregnant women troubled in this way.

So it is that the antihistamines have come to fill a most welcome place in medicine and in their various forms, tablets, solutions, ointments and injections, they are helping to make the lives of allergy sufferers more bearable. Make no mistake, they are not by any means life-savers like penicillin or the sulpha drugs, but they are nevertheless a tremendous boon to the physician.

STATIC CHARGES

"Frictional electricity" as taught in junior physics classes, with the accompaniment of experiments involving silk, glass rods, and so on seems remote from practical cases, but electrostatics is by no means only an academic subject.

A modern example of electrostatics on a large scale is in the electrostatic generator, as developed by van der Graaf. An insulating tower contains a vertically running belt with an upper pulley and a collector inside a large terminal of nearly spherical shape. The lower end of the belt runs over another pulley near which is a charger comprising a local generator of some kilovolts. This charge is taken up by the belt and continually increased as the belt passes the initial charger so that at the top the accumulated charge is of the order of megavolts and capable of supplying a small load of a few microamperes.

An application of an electrostatic discharge doing useful work is the dust precipitator, where in a chimney flue a charged wire collects most of the dust which is attracted to it: the dust is thus prevented from escaping up the chimney into the air.

Static charges are frequently found where friction between dry insulating and conducting bodies occurs continuously. Thus leather and rubber belts acquire charges. In the case of paper coming off the rollers in a paper factory, the charge built up may become dangerous. Any such charge tends to build up until it reaches equilibrium between continued charging on one hand and leakage on the other. If the insulation is so good that the charges become considerable, the potential acquired may be sufficient to spark over to some earthed part of the surroundings. In an inflammable atmosphere this can be serious. Some years ago a conducting rubber specially loaded with carbon was developed expressly with the object of eliminating this hazard. Such rubber is for soling footwear worn by surgeons and nurses in operating theatres where induced charges might ignite inflammable anaesthetic vapours.

Apart from the danger of static charges on moving belts, there is also the nuisance value as light oppositely charged bodies tend to adhere and so make handling more difficult. This is an important consideration in textile factories, for example.

The elimination of such static charges is accomplished in various ways, including the provision of a number of earthed points near the charged surface. A modification is to use earthed tinsel or other metal, in finely divided form to touch the charged surface, but this requires contact, which may be undesirable.

Another family of methods is to make the surrounding air more conducting; this may be accomplished by a gas flame—which introduces its own hazards, however—by a nearby electric discharge to ionise the air, or by a radium product, also to ionise the air. This latter solution is quite sound and is now becoming more widely used. A substance emitting α-particles, is provided near the charged surface; it need not be in contact. Various radioactive isotopes can be used for this purpose. It is then only necessary to arrange the ionising source to be within a few inches of the whole width of the paper or other moving belt and action is then continuous and automatic.

The Bookshelf

Chemical Control of Insects. By T. F. West, J. Eliot Hardy and J. H. Ford. (London, Chapman & Hall. Frontiers of Science Series, 1951, 211 pp., 15*s*.)

THIS book should enjoy a wide readership. It will be invaluable to the chemist who needs a compact survey of insecticides, particularly as it gives useful data on the *biological* range of effectiveness of the various chemicals. The biologist who wants a guide to chemicals with lethal or repellent properties should buy it; the gardener who wants to plan a systematic and scientifically ruthless campaign of extermination should acquire it.

Perhaps the chemical bias of the book is a bit too heavy; there are many errors of spelling and typography to offend the biologist, though still more annoying perhaps is the general air of unjustifiable omnipotence vis-à-vis the insects.

"Science" is in no way synonymous with omniscience, especially where pesticides are concerned, as any gardener or farmer could tell you. It is time chemists realised that living organisms with their capacity for variation have a way of striking back against even the most drastic measures of pest control; toxic chemicals inevitably tend to select the toughest strains within a species, a phenomenon encountered when using not only insecticides but also herbicides like the hormone weedkillers.

But the book is most useful: it has collected most of the relevant facts that one needs in order to plan new chemical assaults on pests, and the copious references are very valuable.

A Surgeon's Fight to Rebuild Men. By Dr. Fred H. Albee. (London, Robert Hale, 1950, 270 pp., 15*s*.)

THIS is an autobiography, which is as humble as it is inspiring, by a great American plastic surgeon, who derived his early ideas on grafting by watching his grandfather grafting fruit trees.

In the days when Dr. Alexis Carrel was establishing the principles of tissue culture, Albee started at Cornell University to experiment with bone grafts, transplanting first of all fragments of dogs' leg bones into the split spinous processes of vertebræ. While he was collecting together the fundamental facts about the mechanics and biology of transplanted bone (a transplant is *living* tissue) he also realised the importance of developing new instruments; he designed, for example, the universally used bone mill, which he powered with one of the first fractional horse-power motors to be marketed.

He came to Europe in 1909 and 1913 to demonstrate his techniques of dealing with osteoarthritis and tuberculous hunchback. Like all pioneers he encountered opposition, which, however, was to dissolve in the maelstrom of World War I. The Germans early recognised the importance of his methods, and as part of their preparations for that war they invited him to teach German surgeons. Practically every belligerent country developed plastic surgery during the war.

Albee worked in France, and there is a most interesting passage in the book describing the activities of Dr. Carrel, who was also out there. In the early days of the war, 70% of the amputations were necessary because of secondary infection, not because of the degree of damage. There was, of course, no such thing as penicillin available then, but Carrel in collaboration with H. H. Dakin of Leeds University devised a very effective technique for irrigating wounds with a hypochlorite solution which released nascent chlorine, a most potent disinfectant. Albee comments sharply on the resistance of the medical profession to this and other new techniques; he writes, "The pioneer's greatest stumbling-block is jealousy. When the Almighty passed out jealousy, he gave most of it to the medical profession. The libellous and stupid opposition of members of the medical profession dissuaded younger surgeons from resorting to this [the Carrel-Dakin] method. And those who were loudest in its condemnation were those who had failed to learn and carry out the details meticulously and consequently did not get favourable results."

Albee himself solved some of the most difficult problems arising in bone surgery. He became singularly expert in dealing with jaw cases—many and terrible were the casualties being caused by machine-gun bullets, and soldiers were frequently carried in with their faces literally shot or blown away. For these men Albee created new jaws by grafting pieces of ribs, tibias or pelvic bones. Not only was he able to eliminate the hideous disfigurement otherwise inevitable, but also to restore the functions of the face. Plastic surgery was growing up fast: even substitute fingers were grafted on, and these eventually recaptured some of the lost functions, such as the sense of touch.

The casualties of peace are no less hideous than those of war; in the U.S.A. in an average year road casualties number 36,000 dead and a million and a quarter injured. Limb amputation is also needed in many of the 30,000 industrial casualties that occur yearly. Rehabilitation, which Albee pioneered in the U.S. Army, is just as necessary in these civilian cases. Albee quotes the rehabilitation of 8000 such people at a cost of \$3 million, whose annual earning power represents \$11 million—three, almost four times, the Government's investment in them. Comments Dr. Albee, "It seems to me that, apart from any humanitarian angle, apart from any purely decent and self-respecting angle, rehabilitation has not only justified itself. It has proved, in dollars and cents, that it pays to conserve our human resources."

Dr. Albee's philosophy is heartening to anyone who is troubled about the prostitution of science by our civilisation: ". . . a doctor tends to be an optimist. He is busy and his work, after all, is constructive, not destructive. The fact that his patients have been injured by battle, or modern machinery, or criminal carelessness in driving, does not make the job of curing them less worthwhile.

"I have loved the inventions of my time, electricity, the aeroplane, the motion picture, and I have made great use of them. They do not seem less wonderful to me because men have used them unworthily.

"We have already most of the things we need to make us healthy and happy if we can only learn to use them intelligently. We have gone a little way in discovering the secrets of nature. We will go farther. This is just the beginning—not the end."

Glossary of the British Flora. By H. Gilbert-Carter. (London, Cambridge University Press, 1950, 79 pp., 8*s*. 6*d*.)

IN this day and age few people know enough Latin and Greek to be able to derive much information from the scientific names for plants; even fewer know how to pronounce those names. This book provides all that is needed to bring to life the otherwise dry-as-dust nomenclature of botany; it not only gives derivations and pronunciation, but also gives notes about the origin and significance of the plant-names.

A few examples will demonstrate its value. Look up '*Antirrhinum*', and one finds that the word was coined by Threophrastus; it means 'resembling a nose' and was apparently first applied not to the snap-dragon at all but to *Vallantia*. '*Lilium*' comes from Virgil; '*Mimulus*' (monkey musk) means a 'mimic actor', a very apt description because the corolla resembles an actor's mask. '*Nasturtium*' derives from the 'nose-twisting' connotation, 'nose-twisting' being a fair term for the human reaction to the plant's pungent essential oil. The lovely word *pardalinus*, which is attached for instance to one of the lilies, means 'spotted like a leopard'; '*Polygala*' (milk-wort) implies 'much milk', perhaps because the plant is supposed to enrich pastures and increase milk production. '*Sempervivum*' (house-leek) is another word invented by Pliny; it means 'always alive' and refers to the plant's evergreen character. (The Greek term '*aizoides*' means the same thing and was also applied to an evergreen, probably a sempervivum.)

'*Trifolium*' was also coined by Pliny; it covered plants with shamrock-like leaves, and today it is the general name of the clovers. '*Vicia*' (vetch) is another word used by Latin authors. The Romans, did in fact, know a lot about the clovers, peas and vetches and they used them in their agriculture, realising that legumes increased soil fertility, which we now know is due to the ability of the symbiotic bacteria in the plants' root nodules to fix atmospheric nitrogen.

Semi-conductors. By D. A. Wright. (London, Methuen, New York, John Wiley, 1950, pp. 130, 7*s*. 6*d*.)

MR. WRIGHT's little book provides a useful general introduction to his subject for

those who have some scientific background. After two opening chapters on the behaviour of electrons in solids, he deals in greater detail with thermionic and secondary electron emission and more cursorily with metal-semi-conductor contacts and with photo-electric emission.

Mr. Wright's treatment is largely qualitative and the reader who requires more precise information must consult 'higher authority'. The emphasis is refreshingly different from most works on this subject, which makes the book worthy of the attention of those already familiar with this field of research.

Audubon's Birds of America. (New York, Macmillan, 1950, 320 pp., 22*s.*)

A HUNDRED years ago died a man who was probably the finest bird artist who has ever lived—John James Audubon.

As the foreword to this lovely collection of 288 Audubon paintings remarks, "Much ink has been spilled over whether his claim to fame was primarily as an ornithologist or an artist. In my opinion [the writer is Ludlow Griscom] much of this debate is second-rate or even trivial, and misses the major point. Actually he was both, and it is an irrelevant detail to consider in which field he may have excelled."

Audubon was a great character; the son of a French naval officer and a Creole woman of Santo Domingo, he wrecked his business career because he spent so much time hunting, shooting and drawing, and among the pioneer settlers he was regarded as an incompetent madman. But during this time his dreamy intention to publish a series of paintings depicting every species of North American bird was crystallising. He kept himself by selling pictures and portraits and by teaching drawing. By 1838 he was able to complete his atlas of birds; the whole work cost some $100,000, and he issued under two hundred sets of these bird pictures at $1000 a set. The project took him just about 25 years, a long period of struggle in which he was sustained by his own enormous self-confidence and by the encouragement of his devoted wife, who believed in his genius as certainly as he did himself. He was indeed the type of genius who just cannot be stopped from reaching his objective.

His success was established by that set of pictures. Then, at the age of 55 years, he began the octavo edition of his *Birds of America*; the seven volumes of this great work took him only four years. By 1846 he had completed all of 155 paintings of North American quadrupeds. Completely worn out by now, his health and mind began to fail rapidly and he became totally blind.

Today Audubon is one of the American immortals; his originals are beyond price, and only the rich can afford to collect the earlier octavo editions of his books.

This book reminds us of "what Audubon set out to do and what his contribution was". Audubon had limitations, which is scarcely surprising, for he did not live in a scientific society. He made mistakes—Audubon's Bald Eagle has only eleven tail feathers instead of twelve—but such errors were usually due to misinformation provided by other people in whom he trusted, but who sometimes sent him imperfect specimens. (Quite frequently the specimens he received were inaccurately labelled as to the place of collection.)

Audubon's records are of great historical value, for they portrayed the avian fauna of America before it was decimated by hunters and the traders who sold plumes and cage birds. Several of his birds were to pass out of existence, such as the Labrador Duck and the Great Auk. Comparison of the composition of modern bird communities with those of Audubon's time sheds light on the capacity for adaptation exhibited by the different species, an aspect of evolution of great scientific interest.

To keep his memory green is the National Audubon Society and its local organisations, which secured the protection of every American bird by 1920. An even finer memorial is the result of this protection: over 100 species of birds have increased their numbers, and some species are now as numerous as they were in Audubon's time. This achievement is something we might try to emulate in Britain, for our fauna has suffered even more seriously than that of the U.S.A. in the past two centuries.

To bird-lovers there is perhaps no need to recommend this book. But lovers of good painting may not have come across Audubon's work, but they will appreciate the beauty of his prints, reproduced here by photolithography, the same system of colour reproduction used in our Festival supplement (DISCOVERY, May 1951). Their quality is far higher than that of the flower and bird pictures normally framed and hung on drawing-room walls.

WILLIAM E. DICK

Bee Keeping. By Kenneth K. Clark. (Harmondsworth, Middlesex. Penguin Books, 1951, 222 pp. 2*s.* 6*d.*)

A USEFUL handbook, which interested readers will find valuable. It ought to be read in conjunction with a modern scientific book on bees, such as the one by Dr. Butler of Rothamsted recently published by Oxford University Press.

The Story of Jan van Meegeren: The Master Forger. By John Godley. (London, Home & Van Thal, 1951, 223 pp., 4 illustrations, 9*s.* 6*d.*)

VAN MEEGEREN, whose forgeries of Vermeer and de Hooch set the world laughing at the art critics, succeeded in satirising the false values in which this day and age places so much faith as nearly as did the 'Captain of Kopenick' in a different age and a different society. This story has a scientific side, for Van Meegeren was a good experimental scientist who tried out his techniques of forgery on pilot-plant scale before he went into commercial production. There is also the matter of the scientific detection of artistic forgeries, and the technical experts should always be grateful to Van Meegeren for his demonstration that art experts unsupported by the aids which science can provide are always liable to fall into a snare. He has made the examination of pictures by scientific experts as essential as is, let us say, the expert inspection of drainage and sanitary arrangements.

The Garden Doctor: A Guide to the Health of the Garden. By R. A. Engledow. (London, Bell, 1951, 176 pp. 10*s.*)

THIS compact and inexpensive book, written by the County Horticultural Officer of Essex, deserves a place on every gardener's bookshelf. It is right up to date, and contains practical information that usually cannot be found in books which are even twice as large. Only one query suggests itself: the author seems to be pro-DDT but anti-BHC (benzene hexachloride), and one cannot help suspecting that he has never used BHC himself; his strictures on BHC do not appear to match accepted experience of the users of this insecticide.

A Dictionary of the Flowering Plants and Ferns. By J. C. Willis. (London, Cambridge University Press, 6th edition 1951, 21*s.*)

DR. J. C. WILLIS is one of those inspired compilers, who will tackle any subject that tickles his fancy. One of his best-sellers was his *Tube and Bus Guide to London*; another is this dictionary, of which reprints of the sixth edition have just become available. Anyone interested in plants will find it indispensable, for there is no other book which provides so much information about flowering plants and ferns as this does. Not only is it valuable as a library reference book, but it is just the thing to take along with you to Kew Gardens or any other botanical gardens where the plants are not fully labelled.

It is good to learn that Dr. Willis has 'bequeathed' this book to Kew, so that the staff of that institution can keep it up to date. That places Kew considerably in his debt, a debt which might be partially repayed if Kew Gardens were to add some of the interesting information collected by Dr. Willis to the labels on the specimens growing in the grounds and houses.

Sketching for Craftsmen. By Ernest Hoyle. (City & Guilds series, English Universities Press, London, 1950, pp. 80 with 64 illustrations, 5*s.*)

THIS little book sets out to do a really worthwhile job in which it succeeds quite well. The author, Mr. Hoyle, chief designer in the Ministry of Supply's Telecommunications Research Establishment, obviously knows his subject, though the text has been somewhat let down by some of the illustrations which are rather rough and badly lettered; a book on this subject needs the best illustrations possible. The general layout is clear and easy to read and contributes to a subject which, although involved, has been put over in a very workmanlike manner.

The inability of the majority of technicians, craftsmen and teachers to illustrate their knowledge efficiently is regrettable and it is hoped that in studying this book, they will find it of great value.

FRANCIS RODKER.

Far and Near

Ammonium Nitrate instead of Sulphate

AMMONIUM nitrate is rapidly gaining favour as a fertiliser and may become the preferred material for direct application to the soil, it was stated by Dr. R. C. Tallman, speaking to the American Chemical Society's 119th national meeting.

Although its fertilising properties had long been known, ammonium nitrate had been used before 1943 only in solutions for the preparation of mixed fertilisers. Some ammonium nitrate was released from U.S. Government plants for fertiliser use in 1943, however, and since then the compound has enjoyed a meteoric rise to prominence as a fertiliser material.

"Due to its comparatively high nitrogen content, its wide adaptability to soil and climatic conditions, its comparative resistance to leaching and, probably of greatest importance, its low cost per unit of nitrogen," Dr. Tallman stated, "there are those who feel that ammonium nitrate will eventually be the nearly universal fertiliser of choice for direct application, as well as standing high in the regard of fertiliser mixers." American experience in this connexion is valuable since the production of ammonium nitrate instead of ammonium sulphate would lead to a reduction of the fertiliser industry's demand for sulphuric acid, and so help slightly to ease the critical sulphur position.

New ASLIB Service: A Central Index of Translations

IN order to assist industrialists and scientific research workers to keep abreast of technical and scientific developments made abroad the Association of Special Libraries and Information Bureaux (ASLIB) is preparing a central index of translations. Work has already commenced on this index which will include scientific papers, reports and published articles appearing in foreign journals.

The usefulness of the index will depend on its comprehensiveness, and to make this as wide as possible the co-operation of organisations at present in possession of translations is sought. All such organisations willing to take part in the scheme are invited to get in touch with ASLIB, 4 Palace Gate, London, W.8 (*Tel.* WESTern 6321–3).

Prof. Giauque, Pioneer of Low-temperature Research

THE WILLARD GIBBS MEDAL, one of the highest honours awarded in the American Scientific world, has gone this year to PROFESSOR WILLIAM FRANCIS GIAUQUE, of the University of California, who was awarded a Nobel Prize for Chemistry in 1949.

Professor Giauque is famous for his low-temperature research and he was the first man to demonstrate, in 1933, the magnetic method for approaching absolute zero.

Earlier in his career, he discovered, in association with his graduate students, two heavy isotopes of oxygen—of mass 17 and 18. This work paved the way for the discovery by others of isotopes of carbon and nitrogen and of the hydrogen isotope known as deuterium.

During World War II, he was instrumental in designing and perfecting a mobile oxygen unit for the Services, such liquid oxygen being required as a component of an early rocket fuel and for medical purposes.

The Willard Gibbs Medal Award, founded in 1910 by William A. Converse, secretary of the Chicago Section of the American Chemical Society from 1901 to 1909, is made to "anyone who, because of his eminent work in, and original contributions to, pure and applied chemistry, is deemed worthy of special recognition." It is bestowed annually. Although the medal is awarded by the Chicago Section, selection is made by a jury which is national in character.

Among previous recipients of the medal are Madame Marie Curie, discoverer of radium, Leo H. Baekeland, Harold C. Urey, Irving Langmuir, Peter J. W. Debye and Carl S. Marvel.

Vitamins and Cancer

CANCER formation by one of the most potent known carcinogens has frequently been prevented in animals in a three-year series of experiments through the use of large doses of vitamin B-2, a Rutgers University research team has discovered vitamin B-2—riboflavin—apparently neutralises the carcinogen, by converting it into harmless substances easily disposed of by the body. Once cancer starts growing, however, the vitamin alone does not affect a cure.

The Rutgers research, conducted on rats and designed to find out how the toxicity of carcinogens can be eliminated, has far-reaching implications in that it may open the way to protection of workers against certain types of cancer induced by carcinogenic compounds met with in industry. A defence against cancer, based on vitamin pills, is still a long way off, of course, but suggests the fundamental research now under way at Rutgers may ultimately lead.

The specific agent whose effects are under study is 2-acetylaminofluorene, a chemical which has been employed in the dye industry. It was being considered as a potential insecticide when its carcinogenic nature was discovered, and this promptly disqualified it for insecticidal purposes. The compound's cancer-causing potency, on the other hand, made it a fitting subject for the Rutgers research since, the investigators reasoned, if they could learn how to neutralise 2-acetylaminofluorene they could probably deal equally well with chemically similar carcinogens of greater industrial importance.

One such substance is β-naphthylamine, which is widely employed in dyes and in the rubber industry, and the Rutgers biochemists are now investigating the possibility of combating the carcinogenic tendencies of this compound with vitamin B-2, and also with pantothenic acid, another member of the vitamin B complex.

In their studies the Rutgers biochemists have found that 2-acetylaminofluorene reduces the retention of protein in the body, possibly attacking the nuclei of the cells. They also have observed varying degrees of vitamin B-2 deficiency in rats which were fed the carcinogen. 2-acetylaminofluorene retards the growth of young rats, and it is found that the addition of massive doses of vitamin B-2 to the diet will permit resumption of normal growth. Although large and continuing doses of the vitamin are required, this can cause no harm, since the body merely excretes any excess of the vitamin.

"Excess riboflavin in the diet prevents all of the toxic effects of the carcinogen by aiding in the destruction of the chemical compound in the body of the animal," the Rutgers investigators state. "In the presence of excess vitamin, aminofluorene is converted into a number of derivatives, which are no longer harmful, and will not induce the growth of cancer. Excess riboflavin in the diet will often prevent the development of cancer in the presence of aminofluorene, but once the cancer starts growing the vitamin alone does not bring about a cure."

Dr. Richter's Record

SINCE the note in our last issue about the Argentine atomic claim went to press we have been able to collect further details about the career of DR. R. RICHTER, who directs the Argentine atomic project.

Dr. Richter is an Austrian who left that country around 1933. Prior to that time he did research on optics with von Traubenberg at the German University of Prague. He went from Austria to the U.S.A. where he did research on theoretical physics with Philipp Frank, and later he moved on to Argentina. He has the reputation of being a good physicist, but before going to Argentina he had done no work on nuclear physics.

The Duke of Edinburgh, F.R.S.

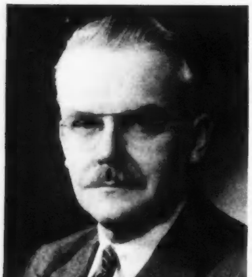
AT the meeting of the Royal Society on May 3, His Royal Highness the Duke of Edinburgh, K.G., was formally admitted into the Fellowship of the Society. The Duke is this year's president of the British Association.

Map of Ancient Britain

THE Ordnance Survey has just published a new map of Ancient Britain with popular appeal, designed for the use of tourists and lovers of the countryside. It shows the position and character of all major visible antiquities in Great Britain which are older than A.D. 1066.

The map is in two sheets, North and South. The scale is 1 : 625,000 or about ten miles to one inch. Symbols are used on the face of the map to show the periods into which the antiquities fall, and this information is further reinforced by an introduction stating the principles on which the map has been compiled. There

New F.R.S.'s



DR. C. S. BEALS

PROF. HERBERT FROHLICH

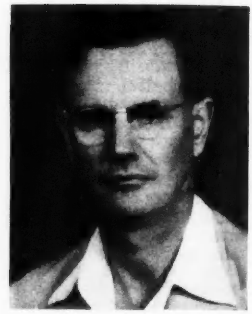
DR. A. H. COOK

DR. S. J. FOLLEY.

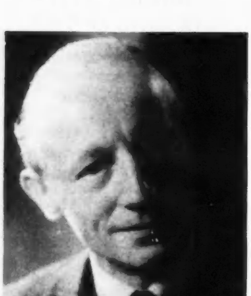
DR. J. S. K. BOYD

DR. G. GEE

DR. GERHARD HERZBERG

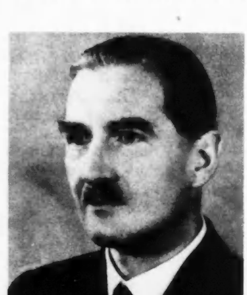


DR. J. B. HUTCHINSON



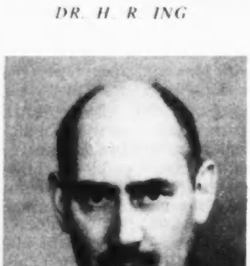
DR. H. R. ING

DR. KURT MENDELSSOHN



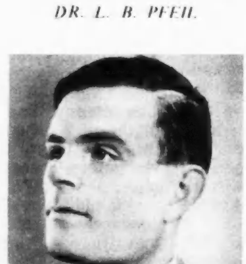
DR. L. B. PFEIL

J. A. RATCLIFFE

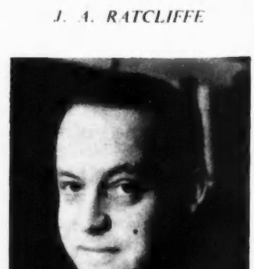


PROF. T. A. STEPHENSON

DR. W. H. THORPE



DR. A. M. TURING



PROF. R. J. P. UBBELOHDE

is also a full alphabetical list of about one thousand names giving a very short account of each site, the number of the Ordnance Survey one-inch sheet on which it will be found, and its National Grid reference. An index of the Ordnance Survey one-inch series is printed on the back of the cover for convenient reference.

Sites have been shown as accurately as the scale permits, against a modern topographical background in grey, which will aid in identifying their positions. The map will be of value in giving a general view of the disposition of different types of site round the country so that visits can be planned, but the closer approach to the sites themselves should be carried out with the aid of the appropriate one-inch sheets. Much care has been taken with the choice of sites to ensure that they are good examples of their kind and easily appreciated by the layman. They range in scope from places connected with the earliest antiquity of man down to Saxon churches. They are only a selection from a vast number available and some sites well known to science will not appear because there is nothing to see on the ground.

These maps may be obtained from Ordnance Survey agents and from most booksellers. The price for each sheet (with foreword, introduction and index of names) is 6*s*. 9*d*.

New Fellows of Royal Society

THE ROYAL SOCIETY has selected the following new Fellows:

Carlyle Smith BEALS. Dominion Astronomer, Ottawa, Canada. Distinguished for his contributions to observational astrophysics, including particularly the study and interpretation of the broadened emission lines in stars with extended atmospheres and of interstellar lines.

John Smith Knox BOYD. Director, Wellcome Laboratories of Tropical Medicine, London. Distinguished for important contributions to bacteriology and immunology. His researches on the dysentery bacilli, the typhus fevers and tetanus led to great improvements in methods of diagnosis and control measures.

David Guthrie CATCHESIDE. Reader in Plant Cytogenetics, Cambridge University. Distinguished for his researches on the cytology and inheritance of plants and animals.

Arthur Herbert COOK. Assistant Director, Brewing Industry Research Foundation, London. Distinguished for his researches in organic chemistry, particularly in relation to fungal antibiotics and the synthesis of heterocyclic compounds.

Sydney John FOLLEY. Head of the Department of Physiology, National Institute for Research in Dairying. Distinguished for his researches into the physiology and biochemistry of lactation, and particularly the influence of hormones on milk secretion.

Herbert FROHLICH. Professor of Theoretical Physics, Liverpool University. Distinguished for the application of quantum theory to the physics of the solid state including particularly the properties of insulators and the interpretation of super-conductivity. He has also made important contributions to the theory of atomic nuclei.

Geoffrey GEE. Director, British Rubber Producers' Research Association. Distinguished for his work on the properties of substances of very high molecular weight, especially rubber and rubber-like substances.

Hans Arnold HEILBRONN. Professor of Mathematics, Bristol University. Distinguished for his discoveries in the analytical theory of numbers and in particular for his work on the class-number of quadratic fields.

Gerhard HERZBERG. Director, Division of Physics, National Research Council, Ottawa, Canada. Distinguished for his contributions to experimental and theoretical physics and chemistry, in particular for his work on molecular and atomic spectra.

Joseph Burtt HUTCHINSON, C.M.G. Director, Central Cotton Research Station, Namulonge, Uganda. Distinguished for his genetical studies of the cotton plant which have led to notable advances in the classification of this genus, and to the theory of the evolution of its species.

Harry Raymond ING. Reader in Pharmacological Chemistry, Oxford University. Distinguished for his investigations on the chemistry of drugs and the chemical aspects of drug action.

David LACK. Director, Edward Grey Institute of Field Ornithology, Oxford. Distinguished for his studies on the behaviour and evolution of birds, especially the formation of species and races of the finches of the Galapagos Islands.

Thaddeus Robert Rudolph MANN. Member of the staff of the Agricultural Research Council. A biochemist distinguished for his researches on carbohydrate and phosphorus metabolism of muscle, moulds, and mammalian seminal fluid, and for his studies on metallo-protein enzymes.

Kurt Alfred Georg MENDELSSOHN. University Demonstrator, Oxford University. Distinguished for his work in experimental physics, especially for his investigations on the properties of liquid helium and of the super-conducting state.

Albert NEUBERGER. Biochemist. National Institute for Medical Research, London. Distinguished for his researches on the biochemistry of amino-acids and proteins.

Leonard Bessemer PFEIL. Director of Research, Mond Nickel Co. Ltd. Distinguished for his contributions to metallurgical research on ferrous and non-ferrous metals.

James Arthur PRESCOTT. Director, Waite Agricultural Research Institute, Adelaide, S. Australia. Distinguished for his investigations on the soil types of Australia, their geographical distribution and relation to climate and vegetation.

Maurice Henry Lecorney PRYCE. Wykeham Professor of Physics, Oxford University. Distinguished for his work in theoretical physics, in particular quantum mechanics and quantum electrodynamics and for his contributions to the knowledge of the properties of the solid state at low temperatures.

William John PUGH. Director, Geological Survey and Museum, London. Distinguished for his researches on the Ordovician and Silurian rocks of Wales.

John Ashworth RATCLIFFE. Reader in Physics, Cambridge University. Distinguished for his contributions to the development of the scientific basis for radio communications.

Thomas Alan STEPHENSON. Professor of Zoology, University College, Aberystwyth. Distinguished for his researches on marine biology, especially on the growth and reproduction of corals and the distribution of animals and plants on the seashore.

William Homan THORPE. Lecturer in Entomology, Cambridge University. Distinguished for his researches on insect physiology and animal behaviour.

Petrus Johann du TOIT. President, Council for Scientific and Industrial Research, South Africa. Formerly Director, South African Veterinary Research Institute, Onderstepoort. Distinguished for his contributions to the study of the diseases of animals, expecially of domestic cattle, and particularly those due to soil deficiencies and to infections transmitted by ticks.

Alan Mathison TURING. Assistant Director, Computing Machine Laboratory, Manchester University. Distinguished for his contributions to mathematical logic and in particular for his work on computable numbers.

Alfred Rene John Paul UBBELOODE. Professor of Chemistry, Queen's University. Belfast. Distinguished for his work in physical chemistry with special reference to structural and thermodynamic questions and reaction mechanism.

New Laboratories for Tin Research

THE new research laboratories of the Tin Research Institute at Greenford were opened on May 31 by the Duke of Gloucester. This organisation is maintained by contributions from the tin miners of Malaya, Nigeria, Indonesia, the Belgian Congo, Bolivia and French Indo-China. It promotes research and also provides a technical service throughout the world, having offices with technical staffs in Britain, the U.S.A., Belgium and Holland.

Chloromycetin saves Aborigines

DISEASES which are not considered very serious in the Western world can do much damage when they break out in epidemic form among isolated communities which have little or no natural immunity to the diseases. Thus from time to time contagious diseases have spread like wild fire among the Eskimos and the Red Indians of America. An epidemic of this kind has just flared up among the Australian aborigines. The disease which is killing aborigine children is whooping cough. Missionaries who are fighting the epidemic among aboriginal children claim to have established a precedent in the use of a rare drug. The Secretary of the United Aborigines' Mission, Mr. Henderson,

says the drug chloromycetin is being used to combat the epidemic, and he believes this is the first time the drug has been used during an epidemic of whooping-cough.

Systemic Insecticides versus Swollen Shoot

SWOLLEN Shoot Disease, which threatens the very existence of the cocoa and chocolate industry (*see* "Plant Viruses and Agriculture", by Kenneth M. Smith, F.R.S., DISCOVERY, Feb. 1950, pp. 36–42), is being fought through the insect which carries the virus causing this disease. The insect involved is the Mealy Bug, and the Colonial Office reports that progress is being made in its control.

A research team sent out by Pest Control Ltd., is working at the West African Cacao Research Institute in Tafo on this problem. A field experiment on 500 trees has been completed in which excellent control of the Mealy Bug was obtained showing a mortality of 99·95% of the bugs. The chemical used is a new systemic insecticide developed for Gold Coast conditions by Pest Control, and this has been named Hannane after Doctor Hanna, the well-known entomologist and leader of the research team.

Owing to the poisonous nature of the insecticide, food crops in close proximity to the treated trees have to be removed. The insecticide is applied to the ground at the foot of the tree and is taken up by the roots and transmitted through the sap stream over the entire tree. The sucking Mealy Bug absorbs the poison while feeding and is killed.

The insecticide kills only the Mealy Bug and the swollen shoot virus in the tree is *not* affected. The insecticide remains active for eight weeks in the tree, and apparently does not harm pollinating insects or beneficial insects which prey on the Mealy Bug.

A field experiment on three acres of swollen shoot infected cocoa is now in progress at the West African Cacao Research Institute on a farm representative of the conditions prevailing in the devastated areas and it is hoped to carry out experiments on a larger scale in areas where isolated outbreaks occur. Although results to date are encouraging it is imperative to secure verification that there is no contamination of the cocoa bean in order to meet with food purity regulations which obtain in Britain and the U.S.A.

Experiments using radioactive tracers show that the insecticide is decomposed in the cocoa plant, and particularly in the pods, so that after the harvesting and fermenting no traces are left in the cocoa beans.

It seems probable that the application of this insecticide together with the cutting out of visibly infected trees will avoid the necessity for more than one or two cuttings and so minimise the number of trees which have to be sacrificed. If everything goes according to the scientists' expectations, widespread use of this systemic insecticide should be possible in approximately six months' time, and it is hoped that this will put the control of the swollen shoot disease in the important cocoa areas of the Gold Coast within reach.

Invasion by a Giant Snail

GIANT African snails, capable of doing great damage in a short time, have been discovered by alert port inspectors in Portland, Oregon, in a shipment of goods from Guam. The snails were destroyed and the entire ship was fumigated before the cargo was unloaded.

During the last war the Japanese brought this giant African snail to the Pacific Islands to serve as a source of food for troops. When the Japanese were driven from the islands the snails multiplied rapidly. Since a single snail can eat a head of lettuce in one night some of the islands were quickly stripped of all vegetation. The snails lay 300 eggs every four or five weeks. At this rate one snail could produce 11,000 million offspring in five years.

Although the U.S. Federal Bureau of Plant Quarantine has made every effort to keep the destructive snails out of American ports, they have turned up elsewhere on the Pacific Coast.

Tetraploid Flowers

NEW tetraploid varieties of flowers are conspicuous in this year's seed catalogues. For instance, Burpee's of Clinton, Iowa, list several tetraploid antirrhinums. These were created from diploid forms by colchicine treatment, and possess *twice* the normal number of chromosomes. (The antirrhinum genus is particularly suited to colchicine treatment as it is characterised by a low chromosome number—*viz.* 16. *A. majus*, the species from which the garden antirrhinum derived, has 16 chromosomes, though a kind with 32 chromosomes was recorded in 1941 by R. Bamford and F. B. Winkler in *Journal of Heredity*.) The tetraploid snapdragons are exceptionally strong, and their blooms extremely large: moreover, many of the flowers are attractively ruffled; the central flower spikes grow 2 ft. and more in height. In the Burpee catalogue there are listed white and pink tetraploids, as well as the Sunset hybrids which range in colour from primrose-yellow flushed pink to rosy bronze. The English firm, Harrisons of Leicester, list the new tetraploid snapdragons.

Tetraploid annual phlox, which originated by colchicine-treatment of selected diploid specimens, is also catalogued by Burpee.

Also of scientific interest are the rust-resistant varieties of antirrhinums; thus one finds in the catalogue of Sutton & Sons Ltd. of Reading, pink and terra-cotta orange varieties which are virtually rust-proof.

Imperial College at Trinidad Celebrates Silver Jubilee

SILVER JUBILEE celebrations marking the granting of the Royal Charter to the Imperial College of Tropical Agriculture at Trinidad took place on March 17, 1951. The College was founded in 1921 and is recognised as the only centre in the British Commonwealth for post-graduate training in tropical agriculture and related sciences.

The occasion also marked the opening of two new research buildings, a large sugar research laboratory and a biology building. These provide facilities for research on bananas, cocoa, soils and sugar technology, and are financed under the Colonial Development and Welfare Act, and by the All-Island Banana Growers' Association, the Cocoa, Chocolate and Confectionery Alliance Ltd., and the British West Indies Sugar Association (Incorporated).

Night Sky in June

The Moon.—New moon occurs on June 4d 17h 40m, U.T. and full moon on June 19d 12h 36m. The following conjunctions with the moon take place:

June			
2d 21h	Mercury in conjunction with the moon	Mercury	7° S
8d 18h	Venus ,,	Venus	1° S
13d 07h	Saturn ,,	Saturn	4° N
27d 01h	Jupiter ,,	Jupiter	4° S

The Planets.—Mercury, in superior conjunction on June 25, is a morning star for more than half the month but is too close to the sun to be seen. On June 30 the planet rises half an hour before the sun but is still too close to the sun to be observed. Venus is an evening star, setting at 23h 20m, 23h 05m, and 22h 40m on June 1, 15, and 30, respectively, and is prominent in the western sky, stellar magnitude about −3·8, the visible portion of the illuminated disk varying between 0·6 and 0·47; the decrease can be easily detected with a small telescope. Mars is still too close to the sun for favourable observation. Jupiter rises at 1h 45m, 00h 55m, and 23h 58m at the beginning, middle, and end of the month, respectively and can be seen for a few hours before sunrise, stellar magnitude −1·9. At the middle of June the planet is a little south of δ Piscium and its easterly movement will be noticed by comparing its positions from night to night with reference to this star. Saturn sets at 1h 30m, 0h 35h, and 23h 35m on June 1, 15, and 30, respectively, and is easily recognised close to β Virginis.

Those who are interested in the occultations of stars can see one on June 23d 02h 43·7m. At this time the star γ Capricorni, magnitude 3·8, is occulted by the moon. The time refers to observations at Greenwich but if a look out is kept some minutes prior to this in other parts of the country it will be seen that the moon gradually approaches the star which finally disappears behind its disk. The actual time of the occultation varies with the latitude and longitude of the place of observation.

Summer Solstice occurs on June 22d 05h when the longest day in the northern hemisphere takes place. In the latitude of Greenwich the sun rises at 3h 42m, and sets about 20h 20m. In equatorial regions there is very little difference in the length of the day all through the year, and at the equator itself the sun always rises about 6h and sets about 18h so that the conditions are similar to those in other countries at the spring and autumnal equinoxes.

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